TITLE "INLAND PILBARA ARCHAEOLOGY: A STUDY OF VARIATION IN ABORIGINAL OCCUPATION OVER TIME AND SPACE ON THE HAMERSLEY PLATEAU"

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Inland Pilbara Archaeology

A Study of Variation in Aboriginal Occupation over Time and Space on the Hamersley Plateau

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This thesis is presented for the degree of Master of Arts of the University of Western Australia

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Abstract

In this thesis I describe the results of my analysis of archaeological material and sediments excavated from four rockshelters on the northeast Hamersley Plateau, Western Australia and synthesise previously reported archaeological evidence from the inland Pilbara to answer two questions about Aboriginal occupation. The first question asks how humans in the inland Pilbara responded to the Last Glacial Maximum (LGM) and compares their response to those of people in surrounding areas. Archaeological evidence from areas surrounding the inland Pilbara, such as the northwest coast, the interior and the Kimberley, indicate that people abandoned sites or used them less frequently during the LGM. A unique and significant feature of the inland Pilbara is the Hamersley Plateau, a massive plateau and escarpment feature that concentrates plateau runoff into long and deep gorges with aquifer-fed pools. Previously reported sites in the inland Pilbara are not near the escarpment and suggest abandonment or reduced frequency of use during the LGM, but I present new evidence from Milly's Cave, located near the escarpment, that indicates increased use during the LGM. This evidence indicates that the pliancy of hunter-gatherer adaptive systems during the LGM may have been underestimated and the local as well as regional environments are significant in understanding hunter-gatherer adaptations to climate change.

The second question asks what technological, economic and demographic changes occurred in the inland Pilbara during the middle and late Holocene and how these changes relate to those in surrounding areas. Located between the northwest coast and the interior, the inland Pilbara has been suggested to be a bridge for populations or ideas moving between the coast and the interior. New Holocene stone technologies appear at similar times in the Pilbara, northwest coast and interior, suggesting the three areas were part of regional systems of technological and economic change. Cultural changes associated with the new technologies are suggested by ethnographic information from the inland Pilbara that links the new technological types to ceremonial activities and gender-specific tasks. Archaeological evidence suggests that late Holocene increases in population dynamics in the inland Pilbara may be related to similar increases in the interior. This evidence suggests that there is a relationship between cultural, technological and economic change and population dynamics in hunter-gatherer populations.

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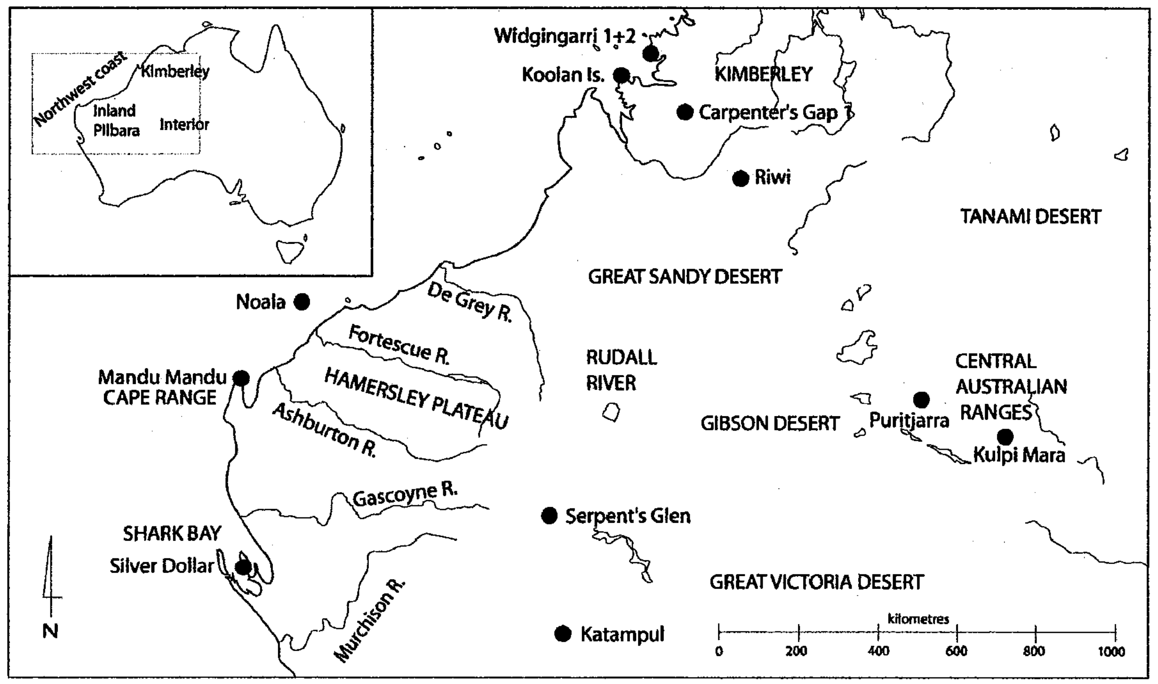
1. Introduction

This thesis presents the results of my analysis of four excavated rockshelters and previously reported evidence from the inland Pilbara region of Western Australia (figure 1.1). The aim of this thesis is to investigate changes in cultural systems and population dynamics during the human occupation of the inland Pilbara by answering two questions:

1. How did people in the inland Pilbara respond to the extreme environmental changes of the Last Glacial Maximum (LGM) at around 18,000 BP, and how and why does their response differ from people in surrounding areas?

2. What are the cultural, economic and demographic implications of the appearance of new stone artefact types and changes in the intensity of site use and the numbers of sites occupied during the middle and late Holocene?

Figure 1.1 Map of places named in the text



The diversity of two questions reflects the diversity of the evidence in the four sites examined here. The four rockshelters examined in detail, Marillana A, Marillana B, Cleft Rock Shelter and Milly's Cave (figure 1.2), were excavated by Lynda Strawbridge during 1989-1993 as part of cultural heritage management activities for an iron-ore mining project by BHP. Prior to my analysis, Strawbridge had obtained some radiocarbon dates indicating that Milly's Cave had a LGM sequence, but the other three sites were probably only occupied during the Holocene. With this knowledge, and a familiarity with problems in inland Pilbara archaeology, I decided that the most productive use of the evidence was to answer questions specific to time periods rather than construct regional chronologies. My approaches to the two questions are linked by the common themes of changes in cultural systems and population dynamics.

Question one

The question of human activity in the inland Pilbara during the LGM is important because it has not been conclusively answered by previous research in the region. The unique plateau and escarpment conditions of the inland Pilbara that suggest that the people living there may have responded differently from those living in the surrounding areas to the environmental changes associated with the LGM.

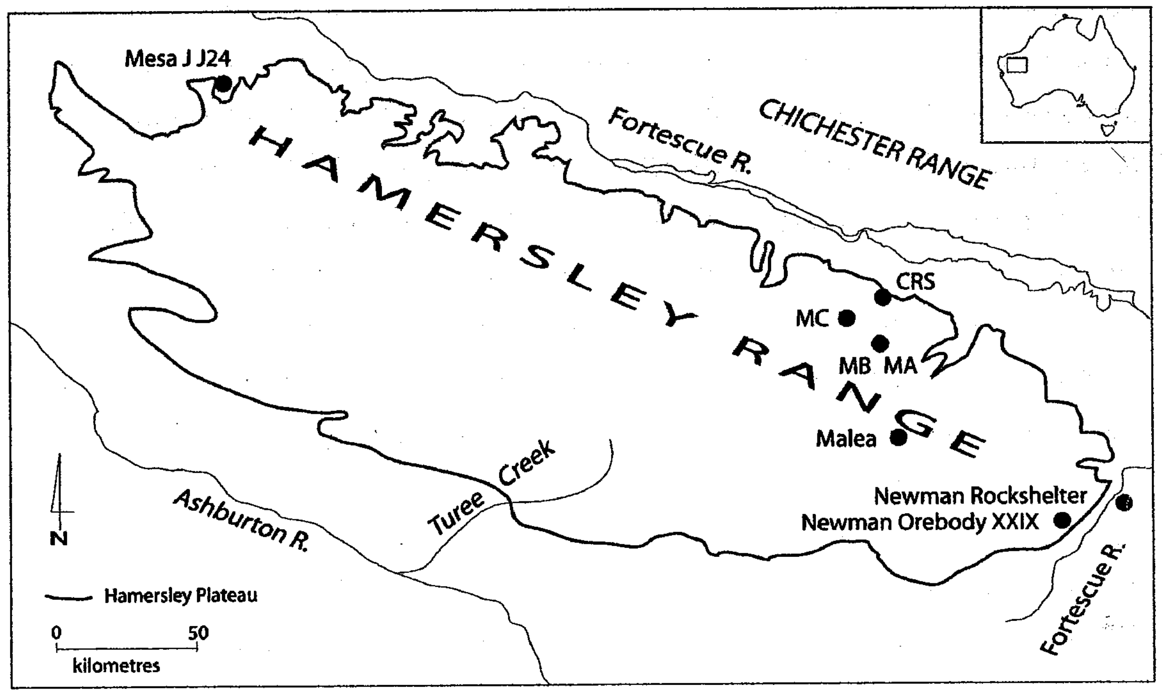
The four previously documented sites in the inland Pilbara occupied before the LGM, Newman Rockshelter, Newman Orebody XXIX, Mesa J J24 and Malea rockshelter (figure 1.2), have low densities of charcoal and artefacts during the LGM. The evidence from Newman Orebody XXIX, the most widely discussed of the four sites, has been interpreted by Brown (1987:23) and Smith (1988:305) as indicative of uninterrupted occupation over the LGM, but Hiscock (1988:263) and Veth (1989:242) interpret the same evidence as abandonment of the site by humans during the LGM. The opposing interpretations of the evidence from Newman Orebody XXIX and the small number of other sites occupied during the LGM indicate that the question of LGM occupation of the inland Pilbara has not been convincingly answered by previous research. In chapter two I present a more detailed discussion of the evidence from these four sites, showing that abandonment or reduced intensity of occupation is the most convincing interpretation.

The responses of people living in the inland Pilbara to the LGM are important for understanding the significance of geography in human adaptations to conditions of increased aridity during the LGM. Sites in the Kimberley with Pleistocene sequences, such as Riwi, Carpenter's Gap, Widgingarri and Koolan Island, contain little or no evidence of human occupation during the LGM. Similarly, sites in the interior (such as Puritjarra, Katampul, Serpent's Glen and Kulpi Mara), to the east of the inland Pilbara, and the coast to the west (such as Mandu Mandu Rockshelter, Noala Cave and Silver Dollar) have evidence of abandonment or reduced occupation intensity during the LGM.

Figure 1.2 Map of places in the inland Pilbara named in the text

Sites examined in this thesis:

CRS = Cleft Rock Shelter
MC = Milly's Cave
MA = Marillana A
MB = Marillana B



Although the sites in the three areas surrounding the inland Pilbara are found in a variety of environments, none of the surrounding areas have topography comparable to the inland Pilbara. The most unique and significant geographical feature of the inland Pilbara is the Hamersley Plateau, which is the largest elevated area of land in Western Australia (Beard 1975:71). It comprises the northern third of the area between the Fortescue and Ashburton Rivers (figure 1.2). The Hamersley Plateau is traversed by a series of hills running along a northwest-southeast axis. The valley floors are 550-650 m asl (above sea level), the elevated plains are 700-800 m asl, the hills are generally above 1000 m asl and the surrounding lowlands are 400-450 m asl (Department of Conservation and Land Management 1999:13). A prominent and abrupt escarpment bounds the plateau on the northern, western and eastern flanks of the Plateau where the strata are generally flat-lying. Long spurs rising from the Fortescue River plain indent the northern scarp. Close to the escarpment the plateau has been deeply incised by some spectacular gorges.

It is this escarpment and associated gorges that suggest human responses to the LGM may have been different in the inland Pilbara compared to surrounding areas. None of the surrounding areas have a plateau-and-escarpment geography as big as the inland Pilbara. The scale of the inland Pilbara escarpment is important for human activity during the LGM because it could provide a high volume of water at a time when surface water and precipitation were reduced. Surface water on the Hamersley Plateau drains towards the Fortescue River and Turee Creek (Brown 1987:7). The gorges on the escarpment concentrate and collect the surface water from the plateau as it drains into the Fortescue and some of the larger gorges have permanent, deep, low temperature pools supplemented by groundwater seepage (Dawe and Dunlop 1983:7). The high volume of surface water at the escarpment compared to the surrounding landscape suggests that it would have been a favourable location for occupation by animals and humans during the hyperarid conditions of the LGM, which I describe in chapter two. The absence of similar geographical features in areas surrounding the inland Pilbara may explain the abandonment or reduction of activity by humans in these areas during the LGM. The four sites examined in this thesis are near the escarpment (figure 1.2) and provide an opportunity to investigate the significance of the escarpment for human occupation during the LGM. One of the sites examined here (Milly's Cave) is near a spring that provides potable water, providing an opportunity to investigate the importance of the immediate local environment on LGM occupation.

Question Two

The question of middle and late Holocene changes in culture, technology and demography in the inland Pilbara are important because the relationship of

changes in the inland Pilbara to the divergent changes occurring in surrounding regions has not been explained by previous work. The location of the inland Pilbara between the north-west coast, desert interior and the Kimberley suggests that Holocene changes in the inland Pilbara may have been related to these areas. A further unexplored possibility is that the people of the inland Pilbara may have developed their own unique trajectory compared to groups in surrounding areas.

Although the reaction to the LGM in the three areas surrounding the inland Pilbara appears equivalent from previously reported evidence, in the middle and late Holocene distinctive historical trajectories appear for each of the three surrounding areas. On the Mitchell Plateau, Kimberley there is an increase in occupation magnitude around 3500-2500 BP, coinciding with the appearance of flaked stone points and a shift to *r*-selected bivalves that tolerate higher rates of gathering than the *K*-selected species common in middens during the earlier Holocene (Veitch 1999:362-416). Points appear in the Kimberley at about 4500 BP at Widgingarri but are not associated with changes in occupation intensity (O'Connor 1990:229, 255). On the north-west coast there is an increase in cultural discard at 8500-7500 BP at Noala Cave on the Montebello Islands (Veth 1993b) and an increase in the number of newly occupied middens at Cape Range at about the same time, coincident with the stabilisation of sea levels (Morse 1993:113-4). New Holocene stone technology on the north-west coast first appear as backed artefacts and seed-grinding implements after about 3000 BP (Morse 1993:257). In the interior, backed artefacts appear after around 3600 BP and use of seed-grinding implements intensifies at the same time (Smith 1988:247) but increases in occupation magnitude do not occur until 1400-600 BP (Smith 1988:330, Veth 1989:175). In answering question two I show how the inland Pilbara relates to these diverse changes.

Jones (1968:10), Mulvaney (1969:115), McConvell (1996) and Veth (2000) suggest that the Pilbara was the entry point or bridge for the flow of ideas (such as the new Holocene stone artefact types) and colonising populations into the interior because of the location of the inland Pilbara as an area between the coast and the interior. If the Pilbara was a bridge between the coast and the interior then the timing of Holocene changes in technology, economy and demography should be between or overlapping the timing of changes on the coast and interior. Previous work in the inland Pilbara by Brown (1987:27) provided a date of 3740±100 BP (SUA-1509) for the first appearance of backed artefacts at Newman Rockshelter and 2440±60 BP (Beta-7215) for Site P5315, but the timing of changes in population dynamics and the first use or intensification of grinding technology have not been established in previous work. In answering the second question I shall discuss how the middle and late Holocene changes in the inland Pilbara relate to changes in the surrounding areas and why those changes may have occurred.

RESEARCH APPROACH

To answer these two questions I present a synthesis of previously reported evidence recovered from the Pilbara and surrounding areas and an analysis and discussion of archaeological evidence recovered from the four previously unanalysed and unreported rockshelters excavated by Strawbridge.

In chapter two I use previously reported archaeological evidence to show that sites in the interior, north-west coast and Kimberley are abandoned during the LGM. I show that although there is contention over the question of abandonment or continuous occupation of the inland Pilbara during the LGM, previously reported evidence suggests abandonment or reduction of occupation intensity. Chapter two also shows that previously reported evidence on the appearance of new stone types and increases in occupation intensity in the inland Pilbara are linked to changes in surrounding regions and the emergence of some cultural systems recognisable in ethnographic literature.

In chapter two I use information from ethnographic literature to link material remains in the archaeological record to cultural activities and systems recorded by ethnographers in the inland Pilbara. When interpreting the archaeological record of the LGM I rely on analogies with common patterns of hunter-gatherer behaviour recorded by ethnographers from groups around the world, rather than focussing on specific groups. The LGM is a period for which there are no contemporary ethnographic analogues and the use of specific groups, such as arctic hunter-gatherers, is flawed because variations in daylight hours, insolation and temperature at mid-latitude zones, such as the inland Pilbara, are quite different from those at artic latitudes (van Andel 1990:33). In addition, linking the archaeological record of the LGM directly to ethnographic accounts is problematic because there are no ethnographic accounts involving hunter-

gatherer groups that have recently experienced long-term climatic deterioration and the onset of glacial conditions (Williams 1998:34).

When interpreting archaeological evidence from the middle and late Holocene I have the advantage of records of Aboriginal hunter-gatherer behaviours recorded by early European visitors to the inland Pilbara. The geographical and chronological closeness of ethnographically documented inland Pilbara Aboriginal groups to the Aboriginal groups that contributed to the middle and late Holocene archaeological record allows for controlled and discriminating analogies between ethnographically documented cultural systems and the archaeological record (cf. Wylie 1985).

In chapter three I present the methods used in measuring changes in population dynamics and cultural systems at the four rockshelters excavated by Strawbridge. I define population dynamics as the forces of people. A change in population dynamics occurs when there is a change in one or more of three variables: (i) the *number of people* in the population, (ii) the *type of activities* they engage in and (iii) the *intensity of activities* they engage in. Chapter three discusses how I identified changes in two of these variables, the type of activities engaged in and the intensity of these activities, by measuring changes in stone artefacts, organic materials and sediment properties. At Cleft Rock Shelter and Marillana A I measured changes in the magnetic susceptibility of the sediments and at Marillana A I measured changes in phosphorus, carbon and nitrogen concentrations in the sediments to detect changes in occupation intensity. These sediment analysis techniques have not been widely used in Australian archaeology and I was interested to evaluate their potential in an arid environment such as the inland Pilbara. Metric and non-metric variables of stone artefacts from all four sites were also analysed to see if changes in stone artefact discard rates were best explained as a result of post-depositional change, changes in the system of artefact manufacture or changes in the intensity of site use.

In chapters four to seven I present the results of my analysis of the artefacts, organic materials and sediments from the four shelters. In chapter eight I provide a synthesis of the results presented in chapters four to seven and answers to the two questions presented here. In chapter eight I also present a discussion of the implications of the results.

2. Archaeological and ethnographic background

Introduction

In this chapter I discuss previously reported archaeological research and ethnographic information from the inland Pilbara to show how previous research has contributed to answering the two questions of LGM occupation and Holocene changes in technology and population dynamics. This chapter summarises the evidence of earliest occupation of the Pilbara to show how human responses changed from pre-LGM environmental conditions to LGM peak aridity. Archaeological evidence from the northwest coast, desert interior and Kimberley is presented to show the human responses that might be expected in the inland Pilbara.

Also in this chapter I present previously reported archaeological evidence from the middle and late Holocene and ethnographic information from the nineteenth and twentieth century from the inland Pilbara to show how they have answered the question of what changes in technology and population dynamics occurred during the middle and late Holocene and how these changes relate to surrounding areas. Particular attention is given to evidence from individual sites, the appearance of new technological types in stone artefact assemblages and the chronological distribution of radiocarbon dates. All radiocarbon dates discussed here are uncalibrated conventional radiocarbon ages (CRA).

Ethnographic accounts of inland Pilbara Aboriginal people provide information on the relationships between some of the political, economic, linguistic, ritual and kinship systems and the new technological types and changes in population dynamics during the late Holocene. The association of ethnographically documented cultural systems with archaeological evidence in the inland Pilbara indicates some of the cultural contexts in which the archaeological record was produced.

Sources of archaeological data

There are two main sources of information on archaeological evidence from the inland Pilbara: unpublished consultants' reports and published journal papers and monographs. The most recent and abundant data are contained in unpublished reports produced by consultants contracted to do cultural heritage management and mitigation for the resources industry. Many consultants' reports are held by the library of the Western Australian Department of Indigenous Affairs (DIA). The DIA is the administering body of the *Aboriginal Heritage Act 1972*, state legislation intended to protect Aboriginal heritage in Western Australia.

However, some reports held by the DIA are not available for public viewing because they contain sensitive Aboriginal cultural information. In addition, the *Aboriginal Heritage Act (Marandoo) 1992* exempts an area of the Hamersley Plateau from the *Aboriginal Heritage Act 1972* so the DIA is not required to hold copies of reports of archaeological work conducted in this area or records of any sites located there. Correspondence with relevant Aboriginal groups allowed me to view some reports but also revealed that number of consultant reports were not available to me (eg. Hiscock and Hughes 1992, Hughes 1992, Thorley 1992, Veitch 1992).

Sampling strategies for collecting archaeological evidence during cultural heritage management projects contains two biases relevant to spatial distribution. Firstly, consultants usually survey areas relevant to their clients. In the case of the Pilbara these are usually areas of underground ore deposits and narrow corridors leading away from them for rail, roads and other infrastructure. The result of this is a form of geological determinism where archaeological sites are most frequently associated with underground ore deposits. Secondly, ethnographic information suggests that Aboriginal people focussed their activity on waterways so archaeologists often focus their surveys on visible water sources. Sites occupied in the past during different conditions of precipitation and evaporation are less likely to be recorded than sites occupied in more recent time. This may result in a bias in the relationship

between site location and the present hydrological regime of the inland Pilbara, possibly limiting the validity of patterns in the spatial distribution of sites.

The second main source of archaeological information for the inland Pilbara is published literature in journals and monographs. Although over fifty excavations have been conducted in the inland Pilbara, publications devoted to Pilbara archaeology are not nearly as numerous. All journal or monograph publications containing primary archaeological data from the inland Pilbara (n=15) span the period 1912 to 1987, when Brown's monograph *Towards a Prehistory of the Hamersley Plateau, Northwest Australia* was published.

To summarise, there are limitations in availability of archaeological information for the inland Pilbara for political, cultural and pragmatic reasons. Most data are contained in unpublished reports, with few publications containing reports of excavations and primary archaeological data.

Pre-LGM occupation in the inland Pilbara

Direct evidence of environmental conditions during the pre-LGM period of 40,000-20,000 BP in the inland Pilbara does not exist, so conditions in the inland Pilbara must be extrapolated from other parts of the Australian arid zone. The nearest evidence comes from a red alluvium unit dated to about 40,000 BP near Geraldton, 800 km south of the inland Pilbara (Wyrwoll 1979:134). The red alluvium indicates more frequent intense rainfall events than today because the alluvium streams have a coarser bed load than present streams, indicating a greater competence and capacity than present streams (Wyrwoll 1979:134). More distant evidence from the Willandra Lakes (News South Wales) and the lakes Frome (South Australia), Eyre (South Australia) and Tyrrell (Victoria) show lake levels at their peak at 40,000-30,000 BP, indicating wetter conditions and permanent water sources in areas that are today quite dry (Allan and Lindesay 1998:212-3, Jones and Bowler 1980:9). After 30,000 BP lake levels decline and a period of extensive inland dune activation and building begins at around 20,000 BP, suggesting a trend towards drier conditions culminating in the LGM at about 18,000 BP (Allan and Lindesay 1998:220).

Human occupation of the inland Pilbara during the pre-LGM period is represented by small assemblages of stone artefacts excavated from four rockshelters. The earliest dated human occupation of the inland Pilbara was excavated by Troilett at Newman Rockshelter (P2055), 14 km from Newman and about 160 m south of the Fortescue River bed (figures 2.1-2.2, Williams 1986:125, Troilett 1982). Charcoal collected from throughout level 16 provided a date of 26,300±500 BP (SUA 1510) for 'near the base of the excavation but not necessarily for the base of the deposit' (Brown 1987:27). Probing of the rockshelter floor with a steel rod by Troilett indicated a further 70 centimetres of deposit below the base of the excavated square, allowing the possibility of human occupation of the rockshelter occurring much earlier than 26,300 BP (Brown 1987:27, Troilett 1982). The excavators do not state why the deposit was not excavated to baserock. Brown's (1987:24-33) analysis of the archaeological material from Newman Rockshelter indicates that from the time of its first occupation to around 26,300 BP there are 41 stone artefacts (15% of the total assemblage) and an unspecified small quantity of charcoal. At Newman Rockshelter the majority of artefacts (64%, n=170) were discarded between dates of 6270±210 BP (WAIT 121) and 3740±100 BP (SUA 1509) (Brown 1987:22-31). The small Pleistocene stone artefact assemblage at Newman Rockshelter consists of unmodified flakes and flake fragments, suggestive of intermittent and brief use of the rockshelter (Brown 1987:31-33).

Identifying the source of the colonising population of the inland Pilbara is difficult because of the paucity of material culture and the absence of any regional styles (such as edge-ground hatchets) in the artefacts from the earliest periods of occupation. The two points of entry closest to the inland Pilbara with early evidence of human occupation are the central Australian ranges and the northwest coast. In the central Australian ranges, across the Gibson Desert to the east of the Pilbara, evidence for human activity begins at Puritjarra at 35,000 BP (figure 2.2, Smith, Prescott and Head 1997). Near to Puritjarra in the central Australian ranges is Kulpi Mara, first occupied at around 29,510±1250 BP (Beta-98034) (Thorley 1998).

Figure 2.1 Map of inland Pilbara sites named in the text

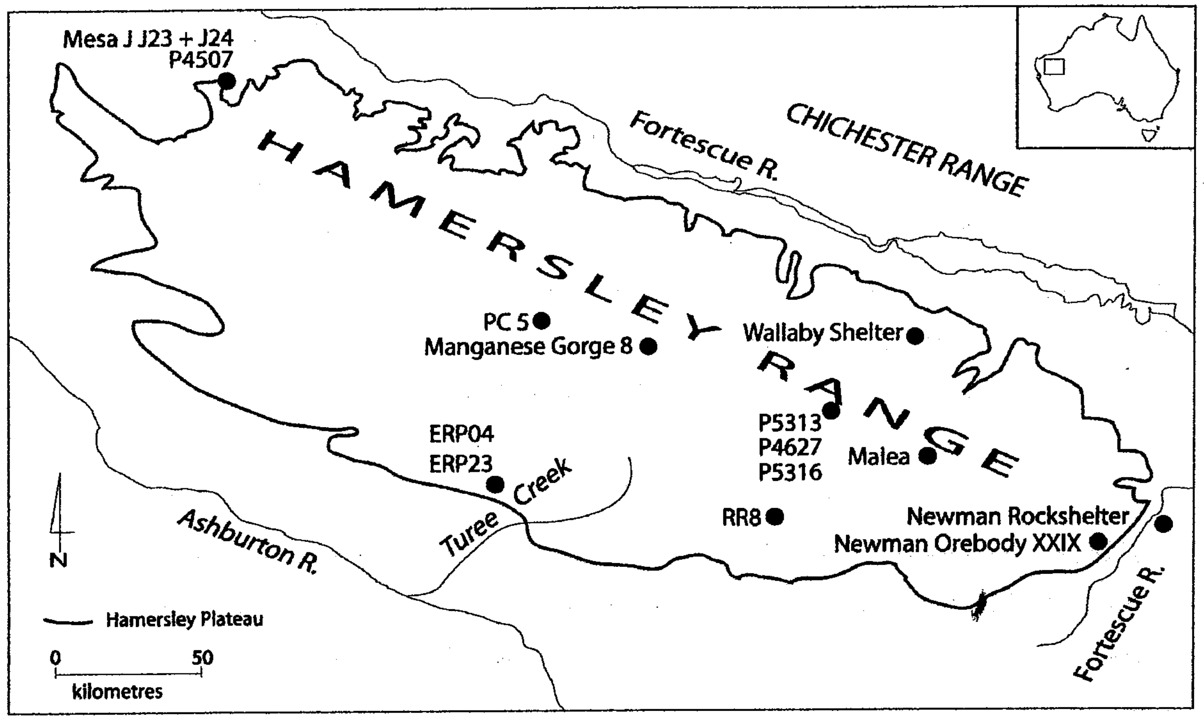
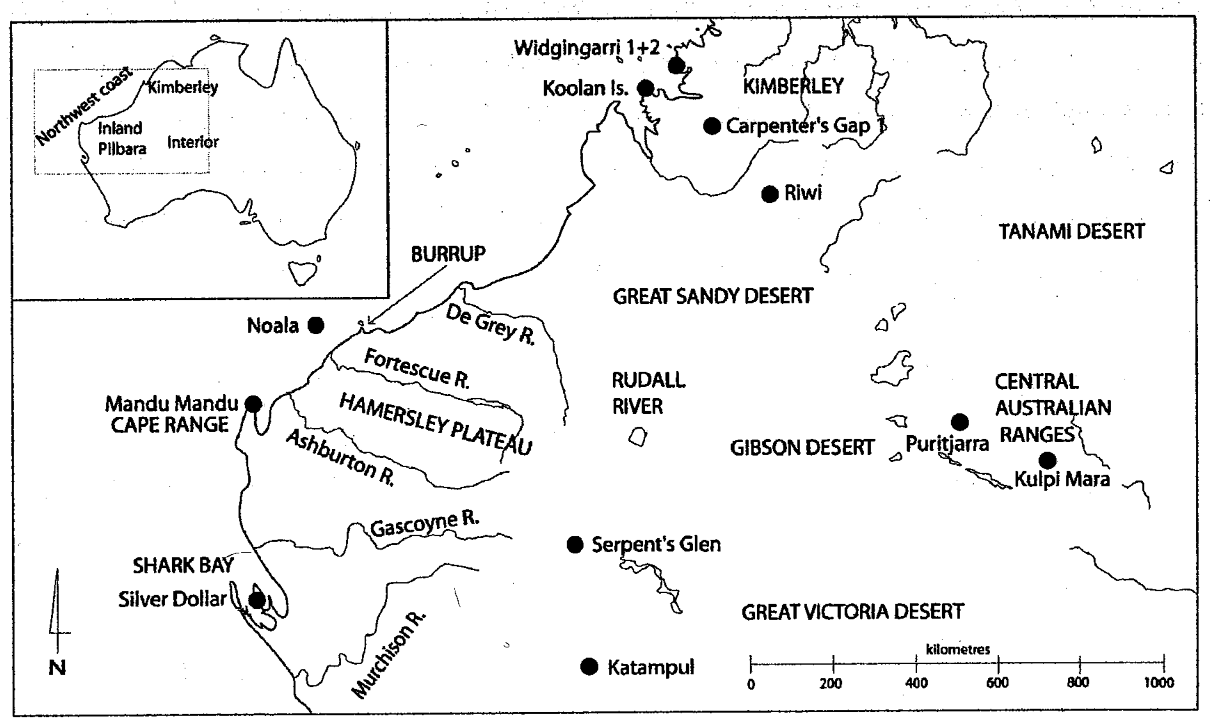


Figure 2.2 Map of sites named in the text in the interior, Kimberley and northwest coast.



At about 32,000 BP stone artefacts and remains of terrestrial and marine fauna were discarded by human at Mandu ManduCreek Rockshelter in the Cape Range (figure 2.2, Morse 1993:141-190). Further south along the coast, human activity is dated to 30,240 BP (ANU-8221) at Silver Dollar in Shark Bay (Przywolnik 1996:21). Ochre dated to between 25,200±250 BP (SUA-2354) and 22,100±500 BP (Wk 1575) at Mandu Mandu Creek Rockshelter provides a link between the coastal and inland Pilbara populations as the Hamersley Plateau is the nearest ochre source to the Cape Range Peninsula (Morse 1993:142, 178). The dates for the earliest ochre at Mandu Mandu Creek Rockshelter and first occupation of Newman Rockshelter are equivalent, within two standard deviations, suggesting that the earliest activity in the inland Pilbara involved coastal populations collecting ochre, among other things, from the Hamersley Plateau. This ochre evidence supports Bowdler's (1990b:339) suggestion that the earliest occupants of the inland Pilbara probably arrived from the northwest coast.

Considering the ochre evidence from Mandu Mandu Creek Rockshelter, the northwest coast is more likely to have been the source of the colonisers of the inland Pilbara than the central Australian ranges. It is possible that the first colonising groups moved out of the central Australian ranges (or elsewhere) and collected ochre as they went through the Pilbara eventually depositing it on the coast, but there is currently no supporting evidence to make this argument (or any other) more convincing than a straightforward movement from the coast into the Pilbara.

Following from Newman Rockshelter, the next earliest date for human occupation is 23,500 BP at Mesa J J24, near Pannawonica, with charcoal from near the bedrock (53-58 centimetres below the surface) dated to 23,500±350 BP (Wk 2514) (figure 2.1, Hughes and Quartermaine 1992:91). Between baserock and the 23,500 BP date are 69 stone artefacts, 31% of the total stone artefact assemblage (Hughes and Quartermaine 1992:91). Associated with the 23,500 BP date are 55 (24%) artefacts and between 23,500 BP and the next date of 3950±110 (Wk 2634) at 22.5-27.5 centimetres below the surface there are 98 (43%) stone artefacts (Hughes and Quartermaine 1992:91-2). The pattern of artefact discard at J24 suggests a peak in artefact discard about the time it was first occupied and then and a very low rate of artefact discard from 23,500 BP until the present. Stone artefact types found in the Pleistocene assemblage at J24 include

flakes and flake fragments but no pieces with secondary working, similar to Newman Rockshelter (Hughes and Quartermaine 1992:94-5). Bones and teeth of mice, macropods and small mammal were recovered from the Pleistocene layers of J24 but no hearths or butchered bones were found (Hughes and Quartermaine 1992:102) suggesting that mammalian carnivores, rather than humans, may have been the primary accumulation agent.

At Malea rockshelter McDonald Hales and Associates (1997) describe a date of 20,950±330 BP (laboratory numbers are not provided) associated with stone artefacts and charcoal at 100 centimetres below the surface and about 10 centimetres above baserock (figure 2.1, McDonald Hales and Associates 1997:20-1). McDonald Hales and Associates (1997:21) do not provide any analysis of stone artefact technology or discard rates but they have a graph of showing numbers of artefacts in each excavation unit. Their graph of artefacts indicates that while stone artefacts occur in all units, the majority of artefacts were discarded after a unit dated to 2,900±90 BP (McDonald Hales and Associates 1997:21). The small proportion of the total artefact assemblage at Malea associated with the 20,900 BP date and the absence of faunal remains, in contrast to the Holocene units, suggests that the early occupation of Malea consisted of brief and intermittent visits.

The first occupation of Newman Orebody XXIX (P0187), southeast of Newman, is dated to around 20,700 BP (figure 2.1, Maynard 1980). A date of 20,740±345 BP (SUA 1041) was obtained by the excavators from charcoal collected from two hearths and a charcoal concentration occurring between 70 centimetres below the surface and bedrock at 100 centimetres below the surface (Maynard 1980:4-7). The 20,700 BP date is associated with 33 artefacts, 13% of the total recovered stone artefact assemblage, compared to 55% (n=115) discarded after a date of 5260±110 BP (SUA 627) (Brown 1987:22-5). No faunal remains were recovered from the Pleistocene period of occupation (Maynard 1980:5). The small number of artefacts and the absence of faunal remains indicate that Pleistocene occupation of Newman Orebody XXIX consisted of brief and intermittent visits.

To summarise, evidence of human activity dating to the pre-LGM period from the four previously reported sites in the inland Pilbara indicate that occupation of rockshelters was not intensive and suggestive of brief and intermittent visits by small groups.

WHAT HAPPENED DURING THE LGM?

Between 23,000 BP and 16,000 BP there was an increase in aridity and surface winds and a reduction in sea levels, surface temperatures and the availability of surface water in Western Australia and throughout the world (Barrows *et al.* 2002, Wyrwoll 1979:129). This aridity resulted from a severe episode of increased glaciation caused by orbitally induced changes in solar radiation (Sturman and Tapper 1996). The aridity peaked at the Last Glacial Maximum (Oxygen Isotope Stage two) at 18,000 BP in Australia (Barrows *et al.* 2002). To provide an impression of the range of responses that might be expected from the occupants of the inland Pilbara, environmental conditions and archaeological evidence from the Kimberley, northwest coast and interior are reviewed to see what LGM conditions were and how people responded to them. Environmental and archaeological evidence from within the inland Pilbara is then reviewed to see how it compares with the surrounding areas.

Kimberley

Analysis of relict dune shape and direction in the Kimberley indicate that conditions in the Kimberley during the LGM were similar to those in the arid zone at the same time (Jennings 1975). Phytolith evidence from Carpenter's Gap 1 in the inland south-west Kimberley (figure 2.2) indicates that the representation of grasslands species of the Kimberley changed little over the LGM although a decline in the abundance of palm and Ulmaceae phytoliths suggest that the LGM was a period of significantly reduced water availability (Wallis 2001). O'Connor (1995:59) writes that 'there is little or no cultural material' associated with the LGM period at Carpenter's Gap 1, but does not give further details. In the inland Kimberley, 90 km east of Fitzroy Crossing, excavation at Riwi rockshelter (figure 2.2) reveals a period of Pleistocene occupation from about 40,000 BP to about 30,000 BP (Balme 2000). Between dates of 29,550±290 BP (Wk 7896) and 5290±60 BP (Wk 7605) there is a stratigraphic and cultural hiatus with 24% (n = 190) of the stone artefacts discarded between these two dates (King 2000:23). Balme (2000) suggests that the absence of a lag deposit at the stratigraphic disconformity makes erosion an unlikely explanation for the hiatus and proposes that occupation at Riwi was at a much reduced intensity at 30,000-5000 BP than before or after. It is worth noting that the period of abandonment at Riwi begins much earlier than the

LGM and it is possible that the initial abandonment of Riwi is unrelated to the LGM aridity.

O'Connor's (1999) interpretation of the Koolan Island and Widgingarri 1 and 2 rockshelters (figure 2.2), on the Kimberley coast and islands of the Buccaneer Archipelago, suggests a hiatus in sedimentation and cultural discard between 18,500 BP and 10,000 BP. During the glacial maximum Koolan Island was part of an inland promontory and may have been abandoned because of the increased distance to the coast. However, the Widgingarri shelters are currently about two kilometres from the coast and were occupied when the coast was more distant several thousand years before the glacial maximum (O'Connor 1999:21-93). In pre-LGM layers at Widgingarri 2 there are 421 (49%) stone artefacts in square B and 279 (30%) stone artefacts in square C (O'Connor 1999:60-64). The abandonment of the Widgingarri shelters suggests that the abandonment of Koolan Island rockshelter may be a result of the relocation of the local population in response to the dry conditions of the glacial maximum rather than the retreating coastline (O'Connor 1999:93, 122).

Northwest coast

The northwest coast experienced similar environmental conditions to the arid zone, although the winds were probably not as strong and stable ocean circulation patterns may have reduced the severity of the shift to glacial conditions (Veeh *et al.* 2000). At Noala Cave (figure 2.2) on the Montebello Islands, 125 km offshore between Onslo and Roebourne, faunal remains and stone artefacts were deposited before a piece of *Geloina* sp. dated to 27,220±640 BP (Wk 2905) at a depth of 48 centimetres below the surface (18 centimetres from the base) (Veth 1993b, pers comm. 2002). A piece of *Melo amphora* from 45 centimetres below the surface of Noala Cave was dated to 12,440±110 BP (Wk 3432) (Veth pers. comm. 2002). The three centimetres of deposit between the 27,200 BP date and the 12,400 BP date suggest that human activity at Noala Cave was much reduced during the LGM or that a period of erosion has removed the deposit.

At Mandu Mandu Creek Rockshelter on the northwest coast (figure 2.2) the discard of artefact and faunal remains peaks between 22,100±500 BP (Wk 1575) and 20,040±440 BP (SUA 2614), then sedimentation and cultural discard cease after 20,000 BP until 5490±80 BP (Wk 1511) when the site is reoccupied (Morse 1993:135-141). The coast was never more than 10-12 kilometres from Mandu Mandu Creek Rockshelter (Morse 1993:4) suggesting that people either left the rockshelter to inhabit the edge of the sea or to occupy inland refuge areas such as the gorges of the Hamersley Ranges. Further south on the coast a similar pattern is found at Silver Dollar where sedimentation continues but cultural discard ceases between around 20,000 BP and 7,000 BP (Bowdler 1990a, Przywolnik 1996).

Interior

Phytolith data from the archaeological site Puritjarra in the desert interior indicate a tree/shrub presence continues throughout the LGM suggesting that the paucity of vegetation and overall dryness of the LGM have been overestimated (Bowdery 1998:122-3). Research into LGM climates at central Australian lakes indicates that while precipitation rates were lower, evaporation rates were also low and the floods from monsoonal storms in the northern most region of Australia enhanced the flow of water into central Australia resulting in increased water levels in the lakes (Nanson *et al.* 1998, Kotwicki and Allan 1998, Nott and Price 1994). The current evidence suggests that the LGM climate of the desert interior included markedly suppressed temperatures, substantially depressed evaporation, high lake levels at major lakes such as Lakes Eyre and Blanche, and probably a less extreme reduction in surface water throughout than has been previously suggested. This may have resulted in an environment more favourable for human occupation during the LGM in the interior compared to the Kimberley and northwest coast.

In the central Australian ranges rates of sedimentation and artefact discard are very low at Kulpi Mara (figure 2.2) between 24,250±620 BP (Wk 4583) at 42-45 centimetres below the surface and 12,060±240 BP at 37-39 centimetres below the surface (Thorley 1998). Similarly low discard and sedimentation rates occur at Puritjarra between 21,950±270 BP (Beta 19901) at 106-117 centimetres below the surface and 12,020±240 BP (Beta 18883) at 93 centimetres below the surface (Smith 1989, 1988:108). The evidence from Kulpi Mara and Puritjarra suggests that people abandoned or reduced their activity in the central Australian ranges

during the LGM even though environmental evidence indicates that the ranges may have been a favourable location for LGM occupation.

Still to the east but nearer to the Pilbara than the central Australian ranges is Serpent's Glen Rockshelter in the Carnarvon Ranges, occupied before 23,550±140 BP (ANSTO 0ZB582) (O'Connor *et al.* 1998). The Pleistocene occupation at Serpent's Glen is very brief, represented by 2% (n=32) of the total recovered stone artefact assemblage, and followed by cultural and depositional hiatus from 23,500 BP until after 4710±180 BP (ANU 10025) (O'Connor *et al.* 1998). At Katampul Shelter, in the northeastern goldfields region to the southeast of the Pilbara, a date of 21,170±190 BP (Wk 3241) was obtained near bedrock at 82-84 centimetres below the surface, although it is associated with less than 1% (n=22) of the total recovered stone artefacts that may not be in their original depositional context (O'Connor and Veth 1996). The 21,100 BP date is six centimetres below a date of 4500±140 BP (Wk 2688) and 77 centimetres of cultural deposit (O'Connor and Veth 1996). The evidence from Serpent's Glen and Katampul indicates that if there is Pleistocene occupation at these sites, it is not during the LGM.

Inland Pilbara

Published environmental data from the inland Pilbara do not extend to the LGM period, but Jones and Bowler (1980) and Allan and Lindesay (1998) have produced reconstructions based on proxy data from lake levels, dune fields and vegetation records from elsewhere is Australia. These reconstructions indicate that the inland Pilbara during the LGM was cooler and precipitation was reduced (Jones and Bowler 1980, Allan and Lindesay 1998). The severity of the decline in the availability of surface water in the inland Pilbara was probably reduced by the aquifer-fed pools protected from evaporation by the deep gorges in the Hamersley Ranges and the concentration of Plateau drainage provided by the northeastern scarp of the Hamersley Plateau.

The evidence from the Kimberley, northwest coast and interior suggests that despite the variation in the severity of glacial aridity between these regions, abandonment or reduction of occupation was a widespread response to the LGM. This suggests that a similar response might be expected from the Pilbara, even with it's uniquely advantageous plateau and escarpment geography.

There are four sites in the inland Pilbara with archaeological evidence relevant to the question of LGM occupation. Newman Orebody XXIX is the most controversial site with Brown (1987:23) and Smith (1988:305) arguing for uninterrupted occupation from 20,700 BP to the present but Hiscock (1988) and Veth (1989) arguing for LGM abandonment. The 20,740±345 BP (SUA 1041) date from Newman Orebody XXIX represents the lowest 30 centimetres of deposit at a depth of 70-100 centimetres below surface, while charcoal from 60 centimetres below the surface is dated to 9870±80 BP (SUA 2553). Hiscock (1988:263) and Veth (1989:242) interpret the depths of these dates as evidence that rates of sedimentation slowed between 20,700 BP and 9800 BP compared to before and after. Hiscock (1988:260-261) uses Newman Orebody XXIX to support his model of fluctuating occupation of the arid zone where sites not located at oases, such as the Hamersley Range gorges, are abandoned between 18,000 BP and 14,000 BP. Similarly, Veth (1989:227-254) uses Newman Orebody XXIX to support his argument, based on biogeographical data of arid zone refugia for animals, that the Hamersley Ranges was a refuge region for humans during the LGM and peripheral regions were abandoned. However, as it is not possible to determine the rate of sedimentation before 20,700 BP or the true time period represented by the charcoal combined to produce this date, I argue the only interpretation available is simply that sedimentation rates increased after 9800 BP.

Without a range of dates between the base of the excavation and the 9800 BP date at Newman Orebody XXIX Rockshelter it is impossible to determine the rate of sedimentation and cultural discard and the sequence of occupation intensity between 20,000 BP and 10,000 BP. In addition, 64% (n=161) of the total recovered stone artefact assemblage occurs after 9800 BP, and only 13% (n=33) are associated with the 20,700 BP date (Brown 1987:25). The presence of artefacts with the 20,700 BP date has suggested to Smith (1988:301) and Brown (1987:33) that Newman Orebody XXIX was intermittently used over a long period with no break in occupation. Smith (1988:296-7, 1989) writes that Newman Orebody XXIX is near the Fortescue River and floodplains, suggesting that it may have been part of an area withdrawn to during the LGM aridity like Puritjarra, which has a similarly sparse occupation signal during the LGM. Brown (1987:55) writes that because of its proximity to the Fortescue River, the Newman Orebody XXIX is on major drainage lines and he considers it an optimal location for habitation. The difference between the opposing views of the Pilbara is that Smith and Brown view the Newman Orebody XXIX as within

a refuge area while Veth and Hiscock view the site as on the periphery of a refuge area. With such small numbers of artefacts and dates, and a small proportion of the total cultural assemblage discarded during the Pleistocene, I believe it is difficult to sustain any general conclusions about patterns of behaviours during the LGM occupation of Newman Orebody XXIX, but a conservative interpretation is that human use was less intensive during the LGM compared to later periods.

Chronological resolution for LGM human occupation at Newman Rockshelter is also low, with the crucial 23,000-16,000 BP period bracketed by dates of 26,300 BP from 120 centimetres below the surface (25 centimetres from the base of the excavation) and 6270±210 BP (WAIT 121) from 43 centimetres below surface (Williams 1986:133). Deposited prior to 26,300 BP are 41 (15%) artefacts and after 6200 BP are 179 (68%) artefacts (Brown 1987:31). Between the two dates in spits 15-10 there are 46 (17%) artefacts, with five artefacts in spit 14, nine artefacts in spit 13 and no artefacts in spit 12 (Brown 1987:31). Hiscock (1988:264) and Veth (1989:242) regard the relatively small numbers of artefacts in spits 12-14 as evidence of a cultural hiatus. Rates of sedimentation and artefact discard at Newman Rockshelter are difficult to assess because no spit depths or sediment details are given. However, the relatively small number of artefacts discarded between 26,300 BP and 6200 BP do suggest a reduction in occupation intensity compared to after 6200 BP.

Chronological resolution for the LGM is also a problem when trying to interpret the evidence at Mesa J J24 (figure 2.1). The LGM period is bracketed by dates of 23,500 BP at 53-58 centimetres below the surface and 3900 BP at 22.5-27.5 centimetres below the surface (Hughes and Quartermaine 1992:91). Between these two dates are 98 (43%) artefacts and after 3900 BP are 58 (25%) artefacts (Hughes and Quartermaine 1992:91). The small number of artefacts discarded between the two dates and the long period between the dates suggests that, like Newman Orebody XXIX, it is difficult to convincingly argue for continuous occupation or abandonment during the LGM at J24. A conservative explanation of the evidence from J24 is that before 23,500 BP and after 3900 BP human occupation events were more frequent than between 23,500 BP and 3900 BP, suggestive of a possible reduction of use during the LGM.

At Malea rockshelter stone artefacts are associated with dates of 20,950±330 BP from about 100 centimetres below the surface and 15,670 BP from about 75-80 centimetres below the surface (figure 2.1, McDonald Hales and Associates 1997). Although exact numbers of artefacts are not given, a graph provided by McDonald Hales and Associates (1997:21) shows that artefact discard is uniformly low from the time of first occupation until 2900 BP when there is a large increase. The low proportion of artefacts discarded between 20,900 BP and 15,600 BP suggest that intermittent and brief visits to Malea continued throughout the LGM. McDonald Hales and Associates (1997:19) state that 'the frequency of rock fragments generally increased with depth, particularly between spits 16 and 18, at a depth of 73 to 97 centimetres'. The depth where rock fragments are most abundant is the same depth bracketed by the 20,900 BP and 15,600 BP dates, representing the phase of LGM occupation. The implications of the concentration of rock fragments at the time of the LGM are not clear because no qualitative or quantitative details of the rock fragments are provided by McDonald Hales and Associates (1997), but it could mean that there was a period of zero or reduced net sedimentation (cf. O'Connor *et al* 1999) during the LGM. If sedimentation rates were reduced during the LGM at Malea then the numbers of artefacts per spit during the LGM are artificially amplified compared to spits representing other periods, suggesting that visits to Malea were less frequent during the LGM.

Veth (1995:736) quotes dates of 17,900±230 BP (Wk 2476) and 8,990±100 BP (Wk 2477) for Manganese Gorge 8 (figure 2.1), near Marandoo, but the dates are out of sequence as the 17,900±230 BP date located two spits above the 8,990±100 BP date. Veth (1995) provides no other details for Manganese Gorge 8 and I do not believe it contains any evidence relevant to the question of LGM occupation in the inland Pilbara.

Evidence of LGM occupation from the four sites with Pleistocene occupation is ambiguous and chronological resolution is low, but the general trend seems to be abandonment or reduced use of these four rockshelters. To summarise the evidence of LGM occupation from the Kimberley, northwest coast, interior and inland Pilbara, there is a uniform pattern of abandonment or reduction of use of sites in these areas during the LGM. In chapter one I suggested that the unique plateau and escarpment geography of the inland Pilbara might provide suitable conditions for human occupation during the LGM. The abandonment or reduction of use at the four inland Pilbara sites may be because they are too far

away from to easily access the concentration of resources at the escarpment. In chapter seven I present evidence of LGM occupation from Milly's Cave, which is located closer to the escarpment and has a different pattern of LGM occupation compared to the previously reported four sites. In chapters seven and eight I explain why Milly's Cave is different from previously reported evidence.

HOLOCENE OCCUPATION

In this section I review the environmental and archaeological evidence from the inland Pilbara to see how previously presented evidence addresses the question of what cultural, economic and demographic changes occurred in the inland Pilbara during the Holocene. Lake sedimentation records and pollen sequences from around Australia suggest that climatic conditions were generally wetter and warmer than today from 10,000 BP to 7000 BP (Allan and Lindesday 1998:228-31, Harrison and Dodson 1993). There is no direct palaeoenvironmental evidence from the Pilbara for this period, but pollen taxa recovered from two dated peat cores in swamps in the Great Sandy Desert, about 500 km northeast of the inland Pilbara, suggests that present conditions were established by 7000 BP and climatic conditions have been stable since (Wyrwoll *et al.* 1986). There is no evidence that Holocene climatic events documented elsewhere in Australia and the rest of the world, such as the Holocene Climactic Optimum, the Medieval Warm Epoch and the Little Ice Age (Allan and Lindesay 1998:229-10, Holdaway *et al.* 2002), had any effect in the inland Pilbara (Wyrwoll pers. comm. 2002).

Although the sequence of human occupation in the inland Pilbara after 10,000 BP is no less ambiguous than the Pleistocene sequence, it has received less attention in the published literature than the Pleistocene period. There are changes in cultural discard and sedimentation rates although these changes do not always occur at the same time and in the same direction at each site. At Newman Orebody XXIX Rockshelter stone artefact discard peaks in level seven (22%, n=54) below a date of 9870±80 BP (SUA 2553) in level six, and again in level three (24%, n=59), between the 5260±110 BP (SUA 627) date in level four and the 3010±85 BP (SUA 1040) date in level two (Brown 1987:22-25). While the excavators do not describe the exact relationship of the excavated levels to the dates, these data suggest that human activity at Newman Orebody XXIX

Rockshelter, measured by stone artefact numbers, was most frequent at around 9800 BP and again during the mid-Holocene between 5200 BP and 3000 BP, with little human activity in the rockshelter after 3000 BP. Other cultural changes at Newman Orebody XXIX Rockshelter include a reduction in artefact size over time (Brown 1987:24) and a reduction in the proportion of artefacts made from locally available banded ironstone formation after 5200 BP. These changes in size and raw material may be related to changes in the technology of artefact manufacture that might explain the increased number of stone artefacts, but artefact technology was not analysed by Maynard (1980) or Brown (1987) so this relationship cannot be tested.

The early Holocene activity seen at Newman Orebody XXIX Rockshelter does not occur at Newman Rockshelter, with only 15% (n=41) of the stone artefact assemblage recovered between 26,300 BP and 6270±210 BP (WAIT 121) (Brown 1987:22-31). At Newman Rockshelter, 48% (n=127) of the total stone artefact assemblage was recovered between 6200 BP and 3740±100 BP (SUA 1509) (Brown 1987:29-31). After 3700 BP only 11% (n=29) of the total stone artefact assemblage was recovered (Brown 1987:29-31). The mid-Holocene increase in artefact discard at Newman Rockshelter between 6200 BP and 3700 BP is probably equivalent to the increase between 5200 BP and 3000 BP at Newman Orebody XXIX Rockshelter. Other cultural changes at the two Newman rockshelters include a reduction in the proportion of quartz and banded ironstone formation artefacts and an increase in the proportion of chert artefacts after spit four, between 6200 BP and 3700 BP (Brown 1987:29).

Newman Rockshelter and Newman Orebody XXIX Rockshelter, like many of the inland Pilbara rockshelters, are in banded ironstone formations, so the increased proportions of chert during the middle and later Holocene may reflect wider ranging for the acquisition of raw materials. Chert has more predictable fracture mechanics than quartz and banded iron formation so the change may also reflect an increased need for higher quality raw materials, perhaps relating the manufacture of backed artefacts and adzes. A further similarity between the two sites is the reduction in artefact discard after 3000 BP at Newman Orebody XXIX Rockshelter and 3700 BP at Newman Rockshelter. It is difficult to make convincing arguments about changes in occupation intensity of Newman Rockshelter and Newman Orebody XXIX because of the absence of detailed technological studies of the assemblages that might show the changes

in artefact discard to be related to technological changes or post-depositional processes.

A similar change in the proportions of quartz, ironstone and chert artefacts is described by (Brown 1987:43-44) for Site P5313 at Packsaddle Ridge (figure 2.1). The archaeological record at Site P5313 consists of 30 artefacts discarded before a date of 2440±60 BP (Beta 7215) obtained from 14 centimetres below the surface and after a date of 8090±80 BP (Beta 7216) obtained from a depth of 22 centimetres below the surface (Brown 1987:33-46). Brown (1987:41-42) notes that the 8000 BP date was obtained from a charcoal-rich hearth and does not represent the bottom of the archaeological deposit where insufficient charcoal was available for dating. Brown (1987:40) does not provide exact excavation unit depths for Site P5313 so it is not possible to relate the sequence of artefact discard to the two dates. With 30 artefacts and two dates from about 100 centimetres depth of deposit, the most parsimonious conclusion is that there was some human activity at Site P5313 around 2400-8000 BP during the mid-Holocene (Brown 1987:33-45). A new technological type appears at Site P5313 as a single geometric microlith immediately below the 2400 BP date (Brown 1987:43).

The first sign of the new Holocene technological types in the inland Pilbara is a backed stone artefact with resin on the backed section associated with the 3700 BP date at Newman Rockshelter (Brown 1987:27). Other new types at this site include five backed artefacts and one adze all deposited after 3700 BP (Brown 1987:29). These new artefact types have been argued to be associated with the appearance of new forms of social and economic organization, such as section systems, large ritual gatherings and risk reduction, throughout Australia (Lampert 1980, Bowdler 1981, Hiscock 1986, 1993, Taçon and Chippendale 1994, Layton 1996). While some of these arguments are plausible, many frequently rely on informal associations and *ad hoc* adaptationist explanations (cf. Gould and Lewontin 1979). The small numbers of new technological types at inland Pilbara sites discussed above suggests that a direct economic function is unlikely, but the small numbers of the new types and the small size of the assemblages they occur in combined with the lack of reporting on technological variables means that testing the different explanations for the appearance of the new types is not possible with current evidence from the inland Pilbara.

New technological forms appears in the desert interior at 3600 BP (backed artefacts and adzes at Kwerlpe, Smith 1988:247), the northwest coast at about 3000 BP (backed artefact at Yardie Well, Morse 1993:257) and in the Kimberley at 4500 BP (points at Widgingarri, O'Connor 1990:229, 255). The first appearance of new technological types in the inland Pilbara at 3700 BP suggests that the new types first appeared in the inland Pilbara, interior and northwest coast at similar times. Assuming that points and backed artefacts are part of a related tradition, the earlier date from the Kimberley indicates that the new technology may have entered the inland Pilbara, interior and northwest coast from the north.

At about the same time as the first appearance of the new technological types there is a proliferation of rock art in the Pilbara. At Skew Valley on the Burrup Peninsula five buried engraved panels were recovered by Lorblanchet (1983) from a stratified midden deposit associated (the exact distances are not provided) with charcoal dated to 3770±80 BP (ANU 1837), 3410±80 (ANU 1839) and 2770±70 BP (ANU 1838). Dragovich (2000) attempted direct radiocarbon dating of rock engravings on the Dampier archipelago using organic components in the varnish overlaying engravings. The five dates obtained were all less than 2800 BP although, in a reversal of the expected pattern, the varnish that was stratigraphically lowest in the sample was the youngest while the top layers returned older dates (Dragovich 2000:3). This reversal may result from reintroduction of old carbon during processes of varnish formation and weathering (Dragovich 2000:3-4). The date of 2,800 BP suggests a date after which the engravings were produced, although the limited understanding of varnish stratigraphy formation and weathering processes limit the validity of these dates.

Bednarik (2002a, 2002b) has attempted to date seven inland Pilbara rock engravings by analysis of microerosion rates. Five of the engravings post-date 3670 BP and two fall in the range of 3670-3191 BP. The accuracy (degree to which the measurement approximates the true value) and precision (repeatability) of Bednarik's (2002a, 2002b) microerosion technique are currently unknown because the results have yet to be repeated.

Palmer (1975) shows that inland engraving sites tend to cluster around and along water sources, such as the Yule and Fortescue Rivers. Similarly, the

engravings on Depuch Island closely follow the water-line, and there are very few engravings on stone surfaces inland, suggesting a close chronological relationship with the current coastline. The majority of engravings on the Burrup Peninsula are located on the granophyre outcrops and screes in the inter-tidal mangrove zones adjacent to the water's edge (Turner 1981:6). The availability of suitable geological formations on the Burrup Peninsula does not influence engraving distributions because similar rock formations are also available inland. The current sea level stabilised around 4000 BP to 7000 BP, and the relationship between the current sea level and engraving location suggests that the engravings on Depuch Island, the Burrup Peninsula and possibly the inland Pilbara waterways have a *terminus post quem* date of 7000 BP (Nakada and Lambeck 1989, Tindale 1987:57).

Other efforts to date major changes in Pilbara rock art are based on superimposed sequences, stylistic chronologies, technique, patination and weathering (Lorblanchet 1983, Wright 1968, Clarke 1978). These methods are problematic because art styles and technique are influenced by the thickness of rock crust and effort required to penetrate the crust (Vinnicombe 2002:22, Bednarik 1995, 2002c). Patination and weathering are not reliable methods for dating because the highly variable and often intense erosion of the Pilbara environment causes degrees of repatination to differ on a single motif (Vinnicombe 2002:22, Bednarik 2002c). While the dating of Pilbara rock art remains problematic and the sample of dated art is small, the similar timing of the fluorescence of rock art and the new technological types may be related to new forms of social organization because in some areas of the inland Pilbara rock art motifs have been associated with sociolinguistic groups and mythological narratives (Palmer 1977a, 1977b, Clarke *et al.* 1978).

Current date ranges for the fluorescence of rock art overlap with an increase in the number of new sites at 3000 BP although these sites typically have shallow deposits and small numbers of artefacts. Site RR8 at West Angelas, 125 km northwest of Newman (figure 2.1), was excavated by Harris (2000) in 10 levels to a depth of 34 centimetres. Level two was dated to 850±50 BP (Wk 8367) and level nine to 4290±60 BP (Wk 8369) (Harris 2000:48). Harris (2000:48, 55) recovered 109 stone artefacts in total, with 49% (n=54) of the total stone artefact assemblage associated with the 850 BP date in level two. A second square excavated at RR8 recovered 152 stone artefacts from nine levels and 38 centimetres of deposit, with a date of 3520±60 BP (Wk 8368) from the fifth of nine excavation levels (Harris 2000:48). Sixty-nine per cent (n = 105) of stone artefacts in the second square at RR8 were discarded after 3520 BP (Harris 2000:54). The new Holocene technology is represented by a tula adze associated with the 3500 BP date (Harris 2000:48). While the exact relationship between the dates and artefact discard is not reported for the two squares at RR8, the peak of discard appears to occur sometime after 4000-3500 BP. McDonald, Hales and Associates (1999) mention a site called SH/N-2 that has dates of 6260 BP and 500 BP but provide no further details.

Powerline Corridor 5 (PC5), 30 km west of Marandoo (figure 2.1), has 49% (n = 101) of the total stone artefact assemblage deposited between dates of 3200±290 BP (Wk 2459) and 3950±50 BP (Wk 2660), but the dates are inverted (Greenfeld 1992). The 3950 BP dates comes from 32 centimetres below the surface and the 3200 BP date comes from the basal spit at 55 centimetres below the surface (Greenfeld 1992:82). The inversion of dates limits the reliability of the evidence from PC5, but a cautious interpretation is that occupation began and was most intensive sometime around 3000 BP.

At Packsaddle Ridge, Site P4627 was first occupied at 2640±130 BP (Beta 7214) and Site P5316 at 2330±50 BP (Beta 7217) (Brown 1987:42). Site P4627 contains 63 artefacts (including one backed artefact) and shows an increase in the proportion of chert artefacts and increase in overall artefact size over time (Brown 1987:44). The small sample of artefacts at P4627 means that these trends may be the result of a few single knapping events rather than representative of patterns of behaviours. Site P5316 contains four artefacts, none of which are new mid-Holocene technological types (Brown 1987:44). The Packsaddle Ridge area is a divide or watershed with water courses draining north and east to the Fortescue River and south and west to the Ashburton River, with the nearest source of permanent water 5.5 km southwest (Brown 1987:34). Brown (1987:46) argues that these Packsaddle Ridge rockshelters (including Site P5131 discussed above) represent a rise in the number of sites and a move towards increased use of the marginal environments such as Packsaddle Ridge after 3000 BP.

Dates of 2490 BP and 340 BP have been obtained for Whaleback Creek Rockshelter but the assemblage remains unanalysed (Strawbridge pers. comm.

2001). Mesa J J23, near Pannawonica (figure 2.1), was first occupied before 2230±160 BP (Wk 2505) and contains 295 stone artefacts including a tula adze slug associated with a date of 650±190 BP (Wk 2503) (Hughes and Quartermaine 1992). Seventy-seven per cent (n = 225) of stone artefacts at J23 were discarded after 2200 BP (Hughes and Quartermaine 1992:85). In the Eastern Ranges, near Paraburdoo, a 10 centimetre deposit at ERP04 (figure 2.1) all four stone artefacts recovered were discarded after 2000±50 BP (Wk 6325) (Hook, *et al.* 1998:31-38). In the same area, excavation of a 24 centimetre deposit at ERP26 (figure 2.1) recovered 28 stone artefacts throughout five levels and a date of 1840±50 (Wk 6327) associated with a hearth in levels three and four (Hook *et al.* 1998:103-110). From these four sites little more can be suggested than an increase in intermittent use of rockshelters after 3000 BP.

Wallaby Shelter (P6107), near Iowa Creek (figure 2.1), has a date of 1730 BP associated with 'a small amount of artefact material' from a 35 centimetre deposit (Strawbridge 1992:38-9). Near Pannawonica, Site P4507 (figure 2.1) was excavated by Kee and Quartermaine (1986) to a depth of 80 centimetres and has a date of 1600±300 (WAIT 12) from 15-20 centimetres below the surface. Associated with the 1600 BP date is 57% (n=98) of the total stone artefact assemblage, with 37% (n=63) of the assemblage discarded before 1600 BP and 6% (n=11) discarded after 1600 BP (Kee and Quartermaine 1986:48-59). These data from Site P4507, and possibly also Wallaby Shelter, suggest that these sites were most intensively occupied around and before 1600 BP with little activity after that time. Grinding fragments were discarded before 1600 BP at P4507 (Kee and Quartermaine 1986:49), providing the first dated evidence of seed-grinding technology in the inland Pilbara. Secure dating of the first appearance of grinding technology in the Kimberley is yet to be produced, but the fluorescence of grinding technology on the northwest coast occurs at about 1500 BP (Morse 1993:178) and in the interior after 1400 BP (Smith 1988:334-8, 1986).

From about 1000 BP to recent times there is evidence of ten rockshelters occupied for the first time. They are spread throughout the inland Pilbara and typically have very few artefacts in a shallow deposit. Table 2.1 is a summary of details of the ten excavated and dated sites first occupied after 1000 BP for which information is currently available. The variation in artefact numbers and absence of a relationship between depth of deposit, age, number of artefacts and artefact density suggests that the formation of the archaeological record at each site is strongly influenced by local conditions.

Table 2.1 Summary of evidence from inland Pilbara archaeological sites dated to after 1000 BP (sites with inverted dates and dated sites with no artefacts excluded)

σ = one standard deviation of the CRA

References

1 Veitch pers. comm. 2001
2 Hook *et al.* 1998:61-6
3 Hook *et al.* 2000:91-9
4 Brown 1987:34-44
5 Hook *et al.* 1998:71-4
6 Veitch and DiLello 2000:39-43
7 Hook *et al.* 2000:91-9
8 Hook *et al.* 1998:39-48
9 Harris 2000:18
10 Kee and Quartermaine 1986:43-8

site name	oldest date (CRA years BP)	1 σ (±)	date depth (cm below surface)	total number of artefacts	artefact density (artefacts m^{-3})	depth of deposit (cm)	reference
CME-A-18	1000	60	0	7	na	na	1
ERP15	950	50	4	7	177	16	2
Y97-28(1)	810	80	0	272	707	38	3
P4623	770	50	8	35	35	100	4
ERP22	560	50	4	1	na	18	5
BM99-10	540	50	4	131	2620	10	6
Y97-28(2)	380	80	14	74	1570	19	7
ERP11b	370	50	8	60	1446	17	8
RR3-O	310	50	10	168	1292	52	9
P4506	120	150	na	335	na	na	10

Although the record from these sites is sparse, they do provide some information about late Holocene occupation. One fragment of *Melo* sp. shell was recovered in association with the 120 BP date from excavations at P4506 (Kee and Quartermaine 1986:46) and a piece of *Melo* sp. on the surface of Y97-28(1) was dated to 810±80 (Wk 5605) (Hook *et al.* 2000:93). The northwest coast is about 450 km from these sites so the presence of marine shell suggests a high level of mobility or the existence of exchange networks including coastal groups for inland Pilbara Aboriginal people during the late Holocene. At RR3–O there are two adzes representing the new Holocene technology in association with the 310±50 BP (Wk 8364) date (Harris 2000:17-25), suggesting that the new technology was present in the inland Pilbara from about 3700 BP to the late Holocene.

To summarise, in this section I have shown that previously reported archaeological evidence provides some answers to the questions of cultural and economic change in the inland Pilbara during the Holocene. New technological types first appear after 3700 BP, possibly associated with the fluorescence of rock art, and last until 130 BP, grinding technology appears or intensifies at about 1600 BP and contact or exchange with the coast occurred after 810 BP. Convincing changes in demography are not evident because of the complex patterns in the timing of increases and decreases in stone artefacts (often the only cultural material at site). A further problem in drawing demographic conclusions from previously presented evidence, expanded on in the next chapter, is that stone artefact counts by themselves are problematic measures of population changes. The absence or brevity of technological analyses of stone artefact assemblages in the sites discussed above means that post-depositional changes and changes in the system of artefact manufacture cannot be excluded as explanations for increases or decreases in the number of stone artefacts.

Distribution of radiocarbon dates

The sparseness of archaeological material at individual sites in the inland Pilbara and the low level of detail in some of the reports suggest that changes in population dynamics and technology may be difficult to identify using a site-by-site approach. An alternative method often employed by Australian archaeologists for producing general patterns of the occupation of sites is analysis of the distribution of radiocarbon dates (Holdaway *et al.* 2002, David and Lourandos 1999, Ulm and Hall 1996, Allen and Holdaway 1995, Smith and Sharp 1993, Bird and Frankel 1991).

I make the assumption that all things being equal, more occupation produces more radiocarbon dates. However, the link between radiocarbon dates and occupation is complex and Rick (1987) has identified three areas where significant biases may potentially occur. First is the bias between the magnitude of occupation and the magnitude of the original carbon deposit, which depends on the activities carried out at the site and the frequency and duration of those activities (Rick 1987:57). The similar types of artefacts and other cultural remains found in the rockshelter excavations throughout time and space in inland Pilbara suggests that similar activities were carried out for similar durations, namely brief visits involving stone and wood working. The unchanging rockshelter function indicates that the assumption of a constant relationship between magnitude of occupation and the magnitude of the original carbon deposit is supported in the inland Pilbara.

The second area of potential biases are those influencing the magnitude of the original charcoal deposit and the magnitude of the archaeological charcoal deposit, which depends on preservation conditions (Rick 1987:57). The unchanging Holocene climatic record from the Great Sandy Desert (Wyrwoll *et al.* 1986) suggests that environmental and rockshelter preservation conditions in the inland Pilbara were stable. The specific preservations conditions at each rockshelter probably vary greatly due to differences in the locations and degree of exposure to wind and water between rockshelters. The lack of detailed sediment analyses in previously reported rockshelter excavations means that biases in preservation conditions at individual shelters are difficult to control.

The third area is biases between the magnitude of the archaeological charcoal deposit and the magnitude of the date sample, which depends on the questions archaeologists are seeking to answer and the funding available (Rick 1987:57). When selecting dates from rockshelters, archaeologists working in the inland Pilbara consider questions of the timing of the first occupation of the inland Pilbara, human behaviour and technology during the LGM, the timing of the first appearance of new Holocene stone technologies and the timing of late Holocene population growth and intensification of social activities (eg. Bednarik 1977:51, Kee and Quartermaine 1986:43-59, Brown 1987:54, Hughes and Quartermaine 1992:94-102, Hook *et al.* 1998:26, Harris 2000:17-49, Veitch and Di Lello 2000:10-1). These questions span the Pleistocene and Holocene periods and suggest that there are no biases for selecting early or late dates. The three areas of bias that can interfere with dates as an indicator of occupation magnitude identified by Rick (1987) are probably not significant problems for the inland Pilbara, except for the differences in individual preservation conditions at each rockshelter, which I have not been able to determine.

In compiling the sample of radiocarbon dates from inland Pilbara sites I have excluded sites that have inverted dates, that have no association between the date and cultural material and sites that are not described in enough detail to be confident of an association with cultural material (table 2.2). The dates are

plotted with 500-year sliding intervals measured every 150 years. The 150-year interval approximates the average standard error of 135 years for the sub-sample of oldest or basal dates (figure 2.3) and 116 years for the total sample (figure 2.4) (cf. Rick 1987:61). The 500-year intervals are arbitrary. The sliding interval smooths out short-term variations while preserving trends in the raw data, but does not account for standard errors of individual samples.

Figure 2.3 shows the chronological distribution of basal or oldest dates at each dated archaeological site excavated to sterile sediments or baserock in the inland Pilbara. Figure 2.3 shows that no new sites are occupied from 20,000 BP until about 15,500 BP. Increases in site occupation occur at 1500-2200 BP and again at about 0-400 BP.

Figure 2.4 shows the chronological distribution of all radiocarbon dates from archaeological sites in the inland Pilbara, displayed in 500-year intervals measured every 150 years (the sample average standard error is 116 years). Figure 2.4 shows similar peak numbers of dates to figure 2.3, occurring at about 1500-2500 BP and 0-600 BP. The similarity in peak numbers of dates in figures 2.3 and 2.4 suggests increases in the magnitude of human occupation at 1500-2500 BP and 0-600 BP.

Figure 2.3 Chronological distribution of all basal or oldest radiocarbon dates (n=25) available from archaeological sites in the inland Pilbara

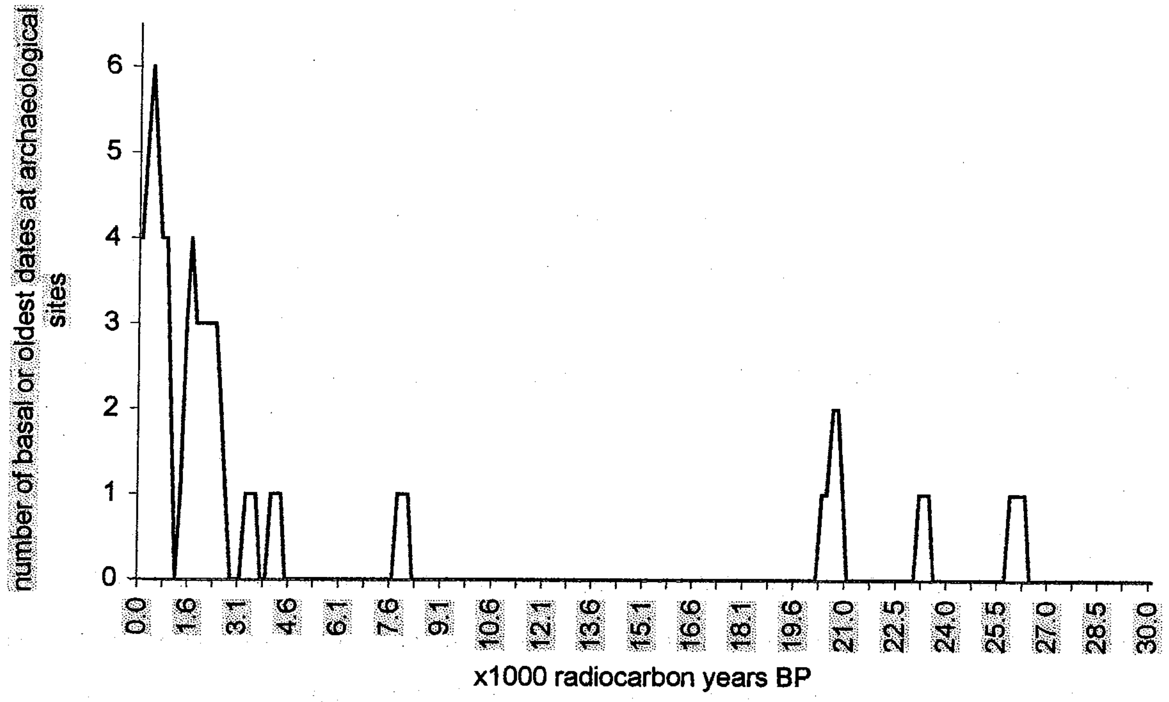


Figure 2.4 Chronological distribution of all radiocarbon dates (n=44) available from archaeological sites in the inland Pilbara

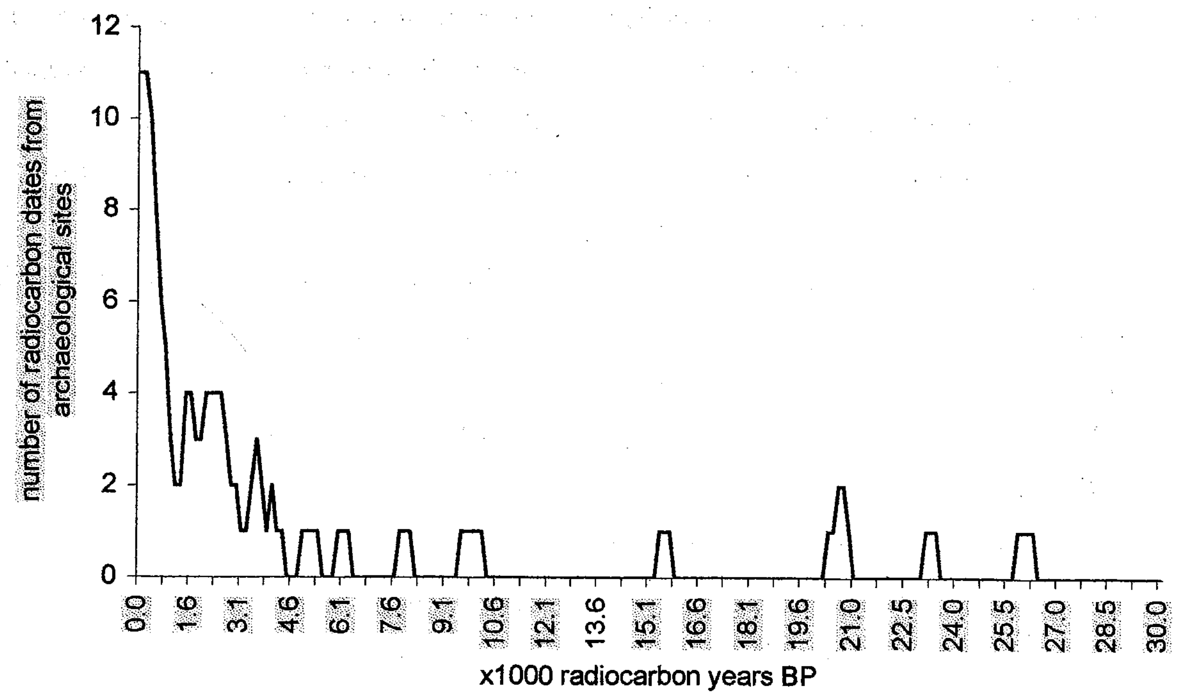


Table 2.2 List of radiocarbon dates from archaeological sites used for figures 2.3 and 2.4. Inversions and dubious archaeological associations excluded. All dates are uncalibrated conventional radiocarbon ages.

CRA = **Conventional radiocarbon age**
σ = **one standard deviation of the CRA**

References

1 Brown 1987
2 Hughes and Quartermaine 1992
3 McDonald Hales and Associates 1997
4 Harris 2000
5 Strawbridge pers. comm.
6 Hook *et al.* 1998
7 Strawbridge 1992
8 Kee and Quartermaine 1986
9 Veitch pers. comm.
10 Hook *et al.* 2000
11 Veitch and DiLello 2000

Site	basal or oldest CRA	1 σ (±)	CRA	1 σ (±)	CRA	1 σ (±)	CRA	1 σ (±)	reference
Newman Rockshelter	26,300	500	6270	210	3740	100			1
Mesa J J24	23,500	350	3950	110	1400	60			2
Newman Orebody XXIX	20,740	345	9870	80	5260	110	3010	85	1
Malea	20,950	330	15,670	240	2900	90	300	50	3
P5315	8090	80	2440	60					1
RR8	4290	60	850	50					4
RR8P	3520	60							4
P4627	2640	130	260	60					1
Whaleback	2490	?							5
P5316	2330	50							1
Mesa J J23	2230	160	650	190	240	80			2
ERP04	2000	50							6
ERP26	1840	50							6
Wallaby RS	1730	110							7
P4507	1600	300							8
CME-A-18	1000	60	390	50					9
ERP15	950	50							6
Y97-28(1)	810	80							10
P4623	770	50	130	50					1
ERP22	560	50							6
BM99-10	540	50	470	50					11
Y97-28(2)	380	80							10
ERP11b	370	50	350	50					6
RR3-O	310	50							4
P4506	120	150							2

Further analysis using Spaulding's (1958) pairwise t-tests of contemporaneity indicates that the sample in table 2.2 contains five pools of dates, summarised in table 2.3. Table 2.3 shows that the middle and late Holocene pooled means of 2383 BP, 1666 BP and 507 BP are similar to the peaks in figures 2.3 and 2.4 at 1500-2500 BP and 0-600 BP. Although the sequences of archaeological materials at individual sites show diverse patterns, the general patterns in the date data presented in figures 2.3 and 2.4 and tables 2.2 and 2.3 indicate that there were at least two major Holocene increases in human activity in the inland Pilbara.

Table 2.3 Summary of dates in table 2.1 pooled according to Spaulding's (1958) method of pair-wise t-tests of contemporanteity. Pooled means calculated using the method of Ward and Wilson (1978).

pool	number of dates in pool	maximum age (radiocarbon years BP)	minimum age (radiocarbon years BP)	pooled mean (radiocarbon years BP)
1	2	21,085	20,620	20,849
2	3	4060	3460	3644
3	7	3095	1950	2383
4	4	1890	1340	1666
5	19	1060	0	507

The inland Pilbara patterns of occupation magnitude suggested by the distribution of dates show some similarities to patterns in the desert interior. Smith (1988:330) describes ten sites with evidence of increased artefact discard at 1400-600 BP in central Australia and Veth (1989:175) describes three sites showing a similar increase in the sandridge desert near Rudall River. Investigation of other desert sites such as Katampul (Cooper 1994) and Serpent's Glen (O'Connor *et al.* 1998) confirms this late Holocene increase in occupation magnitude. Veth (1989:254) and Smith (1988:341-343) argue that this fluorescence in artefact discard and site occupation in the desert interior is related to the emergence of ethnographic desert cultures such as the Martu. Veth (2000) argues that similar formal artefact types, art and mythologies in the Western Desert and the inland Pilbara after 1500 BP indicate movement of the Western Desert language from the inland Pilbara into the Western Desert at around 1500 BP. This archaeological model is an attempt to complement McConvell's (1996) linguistic model. McConvell's (1996) model has been criticised by other Australian linguists (Dench 2001, Dixon 1997:36-7) and Veth (2000:18) writes that it 'is still in the early stage of research' so it is currently difficult to evaluate the accuracy and significance of these linguistic and

archaeological models. At present, the most parsimonious interpretation of the change in the interior at 1400-600 BP and in the inland Pilbara at 1500-2500 BP and 0-600 BP is that there may be some link between the increases in occupation magnitude in the two areas.

The slightly different timing of increases in occupation magnitude between the inland Pilbara and the interior may suggest the direction of change. The increase in the inland Pilbara at 1500-2500 BP slightly precedes the beginning of the increase in the interior at 1400 BP, suggesting that changes in the inland Pilbara may have influenced or caused the changes in the interior. The opposite may be true at the end of the peak at 600 BP in the interior and 0-600 BP in the inland Pilbara, where changes in the interior may have influenced or caused changes in the inland Pilbara. It should be noted that these observations are speculative and sensitive to the sample size of dates. Further analysis of a larger sample of calibrated dates and dates for the first appearance of art styles and artefact types such as prismatic blades or leiliras from the two areas may provide an opportunity to verify the patterns suggested here.

Changes in occupation magnitude in the inland Pilbara and desert interior may be related to changes on the northwest coast and Kimberley. Morse (1993:113) describes seven shell middens dated to between 8000 and 4000 BP, arguing that this increase in occupation magnitude is related to the stabilisation of sea levels around 7000 BP. An early Holocene pattern occurs on the Montebello Islands, off the Pilbara coast, with a peak in artefact and faunal discard at 8500-7500 BP followed by abandonment after sea level stabilisation (Veth 1993b). Veitch (1999:362-417) reports increased occupation magnitude after 3500-2500 BP on the Mitchell Plateau and throughout the Kimberley in the form of increased cultural discard and a shift to *r*-selected bivalves that tolerate higher rates of gathering than the *K*-selected species common in middens during the early Holocene. O'Connor (1990:358) writes that there is a major increase in discard rates at the Widgingarri Shelters at about 1500 BP. This evidence indicates that changes in occupation magnitude in the Kimberley, but not the northwest coast, overlap with changes in the inland Pilbara and desert interior, suggesting that the changes in occupation magnitude in the inland Pilbara and desert interior may have been part of wider regional changes.

The link between the changes in occupation magnitude in the inland Pilbara and interior is interesting because of possible historical relationships (such as Veth's linguistic modelling) and similar environmental conditions. The increases in occupation magnitude at around 1400-600 BP in the interior and 1500-2500 BP and 0-600 BP in the inland Pilbara suggest that the occupants of these two areas were involved in similar changes in the way people used the land and the size and mobility of groups. Change in mobility was probably not a significant factor in the change in occupation magnitude because there are no indicators of major changes in mobility (such as and increase in assemblage diversity or curation) in the inland Pilbara or desert interior.

UNDATED OCCUPATION

The DIA holds details of many thousands of undated Aboriginal sites of different varieties that have been recorded by consultants during cultural heritage management projects. It is not relevant to discuss all of these sites in detail here, although the presence of grinding stones and leiliras are significant for this project because they represent Holocene changes in technology and population dynamics that relate to surrounding regions.

A review of site files and archaeological consultant reports held by the DIA indicates that grinding stones and patches are abundant in open sites and rockshelters throughout the inland Pilbara (eg. Kee *et al.* 1985, Strawbridge 1992, Hook and Jackson 1998, Hook and Veitch 1999). The only site in the inland Pilbara with a date for the appearance of grinding stones is P4507 with a date of sometime before 1600 BP. Grinding stones in the inland Pilbara are significant because they represent a seed-based diet that O'Connell and Hawkes (1981) and Veth (1989:253) have argued to be one of the crucial adaptations that allowed the arid zone dunefield deserts to be colonised after 5,000 BP. If the inland Pilbara is an entry point or bridge for the initial colonisation of the Western Desert, as suggested by Jones (1968:190), Mulvaney (1969:115, 127), Veth (2000) and McConvell (1996), then grinding stones should appear in the Pilbara before 5,000 BP when they appear in the dunefield deserts.

Increased use of grinding technology in the inland Pilbara has implications of cultural change linked to changes in the interior. In the sandridge deserts there is a major increase in numbers of grinding stones after 1400-600 BP coinciding

with substantial increases in occupation intensity at sites in the Rudall River area (Veth 1989:175), the central Australian ranges (Smith 1988:269-292) and at Walga Rock, south of the Pilbara near Cue (Bordes *et al.* 1983). A similarly timed increase in occupation magnitude in the inland Pilbara suggests a related change in economic and social organization. Smith (1988:341) and Veth (1989:253-4) argue that the 1400-600 BP increases in numbers of sites, occupation intensities and grinding activity indicate the emergence of the ethnographic Western Desert culture. The appearance of ethnographic Aboriginal culture in the inland Pilbara may have involved the appearance of cultural phenomena such as the political, linguistic, ritual and kinship systems recorded by nineteenth and twentieth century observers of inland Pilbara Aboriginal people (Dench 2001, McConvell 1985, 1996, Berndt 1980:11, 17, 20-21, Tindale 1974, Withnell 1901). A fluorescence of grinding technology at about 1400 BP in the inland Pilbara would indicate an emergence of ethnographic Aboriginal cultural similar to that argued for the Western Desert.

Another stone artefact type occurring in the inland Pilbara with regional significance is the leilira, or long prismatic blade. The presence of leiliras and leilira quarries in the inland Pilbara is well documented, although none have been found in excavated deposits (Dortch 1972, Clarke *et al.* 1978, Brown 1980:40, 1987:51). The first widespread appearance of leiliras occurs in several sites in Arnhem Land after 3,000 BP (Allen 1989:95-96, Schrire 1982, Kamminga and Allen 1973:88-89, Gillespie and Temple 1976:101, Jones and Johnson 1985:52, 58, McCarthy and Setzler 1960:274). Ethnographic data indicate that in the arid zone leiliras were exclusively used in ritual contexts such as scarification, trade and exchange (Gillen 1968:194, Cane 1984:114-115, Paton 1989:23), while in the north they also were part of a spear-hafting technology and used in hunting and fighting (Spencer and Gillen 1968 [1899]:575).

Trade of leiliras between Arnhem Land and Western Desert populations is well documented in ethnographic literature (Spencer 1928:546, Davidson and McCarthy 1957:449, Gillen 1968:194, 271). Palmer (1977a) provides ethnographic accounts of trade in raw material for circumcision knives throughout the Pilbara region but does not mention external contacts. Although the first appearance of leiliras is currently undated in the inland Pilbara and interior, a conservative prediction would be 1400-600 BP, coinciding with the increases in occupation magnitude. The *Melo* sp. pieces occurring at Y97-28(1) and P4506 dated to 810 BP and 130 BP provide evidence that exchange networks that could have involved leiliras existed in the inland Pilbara after around 800 BP. The appearance of the leilira in the inland Pilbara indicates the operation of regional exchange systems and the expansion of cultural influences from the north.

ETHNOGRAPHIC INFORMATION ON INLAND PILBARA ABORIGINAL PEOPLE

In this section I show how ethnographic evidence provides links between archaeological evidence and pre-contact cultural systems and population dynamics. If the ethnographic record shows an association between cultural systems and behaviours and certain types of material remains, then analogies can be made to the cultural systems and behaviours that contributed to the formation of the archaeological record. In particular, I look at ethnographic descriptions of associations between gender roles and artefact types such as grinding stones and new Holocene technologies, such as backed artefacts, involved in composite tools. Unfortunately, ethnographic information from the inland Pilbara contains no information on the responses of hunter-gatherer populations to short-term climatic fluctuations, which would be of great interest in interpreting archaeological evidence from the LGM.

In assessing the value of ethnographic information in the sources I examine the temporal proximity of the record to the event, the motive of the author, the intended audience and the competence of the observer. These details are important because the value of a written source may be limited by time lapsed between the event and it documentation, the biases resulting from the purpose of the document and its intended audience and the competence of the observer (Wood 1990). The sources examined here include accounts by geographers (Gregory 1884), settlers (Withnell 1901), academic anthropologists (Clement 1903, Brown 1912, Tindale 1974), consultant anthropologists (Clarke and Smith 1982, Clarke 1982, Kee *et al.* 1985) and academic linguists (von Brandenstein 1967, Dench 1995).

Ethnographic information on cultural systems

Gregory (1884) and Withnell (1901) were part of the first European colonising effort of the northwest and because their accounts are designed to make the

Pilbara an attractive location for European immigrants they devote few words to the Aboriginal inhabitants, as Gregory does, or describe them favourably, as Withnell does. Gregory (1884) reports the surveying activities of A.C. and F.T. Gregory who named and crossed the Fortescue River, Hamersley Plateau and Ashburton River in 1861. Gregory (1884:63) records only a single encounter with inland Pilbara Aboriginal people:

> In the course of the afternoon we came suddenly upon a party of natives, digging roots. One women, with a child of about five years of age, hid close to our line of march, and did not move until she was afraid of being run over by the pack horses, when she ran away, leaving the child gazing upon the monster intruders with a look of passive wonder. It was a poor, ill-conditioned-looking object, suffering from a cutaneous disorder. On giving it a piece of damper, it quickly began to devour it, tearing it to fragments with its sharp and attenuated fingers, with all the keenness of a hawk. We left it standing with a lump of bread in each hand, where its mother would no doubt find it when she came to see what had been left of it by the *large dogs*, as the aborigines of this part of Australia call our horses.

In describing the child as a sexless 'object' and suggesting that the mother-child bond is weak or non-existent, Gregory (1884) indicates to readers that inland Pilbara Aboriginal people are non-human or sub-human and are not threatening to potential settlers of the region. Elsewhere Gregory (1884:96-7) writes:

> I would give it as my opinion that these people will not prove particularly troublesome to the settlers, if properly and fairly treated. They are not numerous, and appear very willing to take employ under Europeans, and will no doubt soon be made as useful as in other districts.

The disinterest of Gregory (1884) in describing Aboriginal people as anything but 'passive' and non-human results in his account containing little detail on Aboriginal culture and technology and almost no information relevant to technology and population dynamics. The 'cutaneous disorder' suffered by the child may indicate an infectious disease or malnutrition suggestive of population increases (Webb 1995), but a sample of one means that it could be just an isolated case (perhaps of an introduced European pathogen) with no implications of demographic change.

To the north of the Hamersley Plateau, at the Sherlock River, Gregory (1884:71) describes

> several natives... employed in capturing partridges by means of nets constructed out of the leaf of the triodia neatly twisted and netted in the same way as done ourselves, the mesh varying from one to five inches, according to the purpose to which it is applied... In this way they must capture a large amount of game, judging by the quantity of feathers around some of the waterholes.

This passage indicates that Gregory believed Aboriginal people were not entirely inhuman but capable of some technical expertise and useful as workers to settlers. The mention of nets by Gregory and Clement (1903:7) indicates that trapping was a frequent activity, suggesting intensive economic activity similar to that described by Lourandos (1983) as evidence of a late Holocene intensification of social and economic relations. On the other hand, the use of nets for catching birds in the inland Pilbara may be an ancient activity unrelated to intensification, because net use for fishing is 30,000 years old in western New South Wales (Balme 1995).

The use of nets for catching birds, fish and kangaroos is also described by Withnell (1901:19-22). John Gregory Withnell (1901) was a child of the first permanent residents in the Pilbara, John and Emma Withnell, who arrived at what became Roebourne in 1864 when John Gregory Withnell was two years old (Taylor 1980:37). John and Emma Withnell's time at Roebourne has been documented by their grand-daughter Nancy E. Withnell Taylor (1980) who describes their relationship with local Aboriginal people as harmonious. Little is known about John Gregory Withnell, who wrote and privately published *The Customs and Traditions of the Aboriginal Native of North Western Australia* (1901), except that he lived and worked on station properties owned by his family in the inland Pilbara and other parts of the northwest for at least 20 years. The influence of his parents' peaceful relationship with Aboriginal people is clear in Withnell's preface to his book:

> The object of this work is preserve, before civilisation has made them obsolete, the traditions and customs of the aboriginal natives of the North West of Western Australia - particularly those of the Pilbarra district - as accurately as possible, based upon upwards of twenty years' observation.

Withnell's account does not contain the same biases as Gregory (1884) and the peaceful relationship his parents had with Aboriginal people probably allowed him greater involvement in Aboriginal society than Gregory. However, the brevity (37 pages) means that his account of the Kariera and Indjibandi tribes to the north of the Hamersley Plateau is 'unfortunately scanty' (Brown 1912:144).

There is no direct discussion of Aboriginal technology or population dynamics in Withnell (1901), but there is a frequent association of women with collecting and preparing grass seeds (Withnell 1901:7-9, 16, 23). This is unlikely to be a bias of Withnell's as the same association was recorded from Aboriginal informants much later by staff of the Aboriginal Sites Department of the Western Australian Museum:

> The men were responsible for hunting large game and the women for providing the bulk of the diet more dependably from food plants and small animals (Clarke and Smith (1982:13).

The significance of the division of labour that results in the relationship between women and seed food observed by Withnell (1901) and Clarke and Smith (1982:13) is that it represents a late Holocene change in gender roles. While there is only one previous report of dated grinding material from the inland Pilbara, grinding activity in the desert interior increases greatly after 1400-600 BP, suggesting that activity related to seed food intensified at that time. The role of women in Aboriginal culture may have changed as seed-related subsistence activity increased because they had less opportunity to participate in other types of activities.

Further evidence for the link between late Holocene technological and subsistence change and changes in gender roles comes from Hamilton's (1980) study of the stone technology of Western Desert Aboriginal people. Hamilton (1980) observed that the hafted implements associated with backed artefacts were used only by men amongst Western Desert groups while women generally used only hand-held implements such as grinding and pounding stones. This shows that the introduction of backed artefacts and the fluorescence of grinding technology amongst Aboriginal people of the Western Desert, and probably the inland Pilbara, resulted in a change in the division of stone technology and subsistence tasks between men and women from some unknown previous situation to the situation recorded by ethnographers.

Withnell's association of women and seed foods in the inland Pilbara is also linked to ritual activity. Withnell (1901:9) writes:

> Up to about the age of fourteen the boys are allowed to eat anything, but they are now recognised as young men and have to go through the initiation of manhood, which they call "buckley", known to us as circumcision. Prior to this season the women store a large quantity of grass seeds, etc., so as to have a supply in readiness for the feast, which is a feature of this ceremony. The families then meet at some given spot, the time being arranged by the stages of the moon, as "new" or "full", until the company present is of vast numbers.

Information collected by Clement (1903:9-11) from interviews with Aboriginal people during his visit to the northern Pilbara in 1896-8 corroborates Withnell's account:

> When the boys are about 14 years old, an Invitation-stick (*gilliana* or *cugina*) is carried around from family to family, scattered over the territory of the tribe at the various waterholes and hunting grounds, and a meeting-place is appointed on a certain new moon, to which men, women and children repair. Several weeks before this takes place, the women lay in an abundant supply of food-seeds of all kinds, as they are not only wanted for the great feasts that take place on this occasion, night after night, but, as we shall presently see, for another important function at the end of the "*buckli*"-ceremonial. [...] At night, huge fires are kindled, and the elders sit around them with the candidates, teaching them the laws and traditions of the tribes, the boundaries of their territory, the reasons of their feuds with other tribes, etc. etc. and the strict lines of their future conduct are clearly laid down for them. [...] After three weeks, when a perfect healing [of the circumcision wound] has taken place, another large Corrobboree is held, edible seeds of every kind are placed before them by the elders, and touching these with there hands, it is intimated to them, that henceforth they are welcome to hunt in every part of the territory, where seeds are grown.

The accounts of Withnell and Clement suggest that initiation ceremonies were dependent on the collection, storage and preparation of seeds by women. This suggests that the ethnographically documented forms of ritual activity, such as the circumcision rituals recorded by Withnell and Clement, may have first appeared or become more important at the same time as the intensification of grinding activity. While ritual activity and differences between men and

women undoubtedly existed prior to the introduction of the new stone technology, the appearance of backed artefacts and grinding material indicates that these cultural systems have changed and are more visible archaeologically. If the associations between cultural systems and backed artefacts and grinding implements are reliable, then the archaeological evidence discussed earlier in this chapter suggests that changes in gender roles may have occurred at about 3600 BP (first appearance of backed artefacts) and 1400-600 BP (increased use of grinding technology) in the Western Desert and around 3700 BP (the earliest backed artefacts) and 1600 BP (earliest grinding material) in the inland Pilbara.

Ethnographic information on population dynamics

The three earliest ethnographic sources, Withnell, Gregory and Clement, provide little information that could be useful for modelling past population dynamics in the inland Pilbara, such as the distribution of political and linguistic groups. Some of this information was later collected by academic anthropologists and linguists who were often more interested in mapping tribal and linguistic boundaries rather than cultural description. These tribal and linguistic maps provide evidence of inland Pilbara Aboriginal population dynamics around the time of European contact. The maps and accompanying commentary may reflect the spread of ideas and behaviours, such as types of initiation rituals. Fission and fusion of groups may also reflect cultural changes and changes in the numbers of people in areas of the inland Pilbara.

Brown's (1912:143) map (figure 2.5) is the earliest map of Aboriginal groups produced for the inland Pilbara. The map is based on information he collected during interviews with Aboriginal people during his visit to the area in 1911 (Brown 1913:145). Brown (1913) also published ethnographic notes on the Kariera, Ngaluma and Mardudunera, describing their kinship and initiation systems, noting that these three groups initiate young men by bicep binding rather than circumcision like some of their neighbours. Brown's (1912:143) map is unreliable because he admits:

> the exact position of the more inland tribes is open to some doubt as I was unable to penetrate so far into the interior owing to the drought from which the country was suffering at the time of my expedition.

Connelly's (1932) map of tribes is unannotated except to state that the map was compiles from 'various notes, together with his own observations and that of others' (figure 2.6). Connelly (1932) divides the 33 groups he recorded into coastal non-circumcising groups and inland circumcising groups. Tindale's map published in 1940 and published again with annotations in 1974 is the most extensive account of tribal distribution and relations (figure 2.7). Tindale's (1940) map is based on interviews with Aboriginal people during fieldwork throughout Australia during 1938-9. Von Brandenstein's (1967) linguistic map, based on interviews conducted with Aboriginal people during 1964-7 contains more information about language differences than Tindale, but he provides little detail on tribal relations (figure 2.8).

The usefulness of the maps as information on Aboriginal population dynamics is diminished by differences in the sampling strategies used by each researcher and the increasing effect of European occupation on Aboriginal populations. The impact of European settlement from the mid-nineteenth century, even prior to the first settlement in the area with the spread of European pathogens, probably interrupted the historical processes controlling political and linguistic boundaries so that all of the available maps contain some distortion of the immediate pre-contact situation.

More useful than maps are the ethnographic, biological and linguistic details recorded by Brown, Birdsell, Tindale and Dench which suggest processes of shifting boundaries and fission and fusion of populations of the inland Pilbara sociolinguistic groups that are probably analogous to ones operating prior to European contact. Tindale's (1974) map shows that the Kuruma and Pandjima sociolinguistic groups occupy most of the Hamersley Plateau. The Kuruma group lived in the plateau tops of the Hamersley Ranges in the northwest half of the Hamersley Plateau. The Pandjima are the eastern neighbours of the Kuruma and occupy the scarp and upper plateau of the Hamersley Range. Tindale (1974:15) notes that in the Hamersley Ranges ecological and physiographic boundaries generally define the locations of sociolinguistic groups.

Figure 2.5 Brown's (1912) map of inland Pilbara Aboriginal groups. From von Brandenstein (1967)

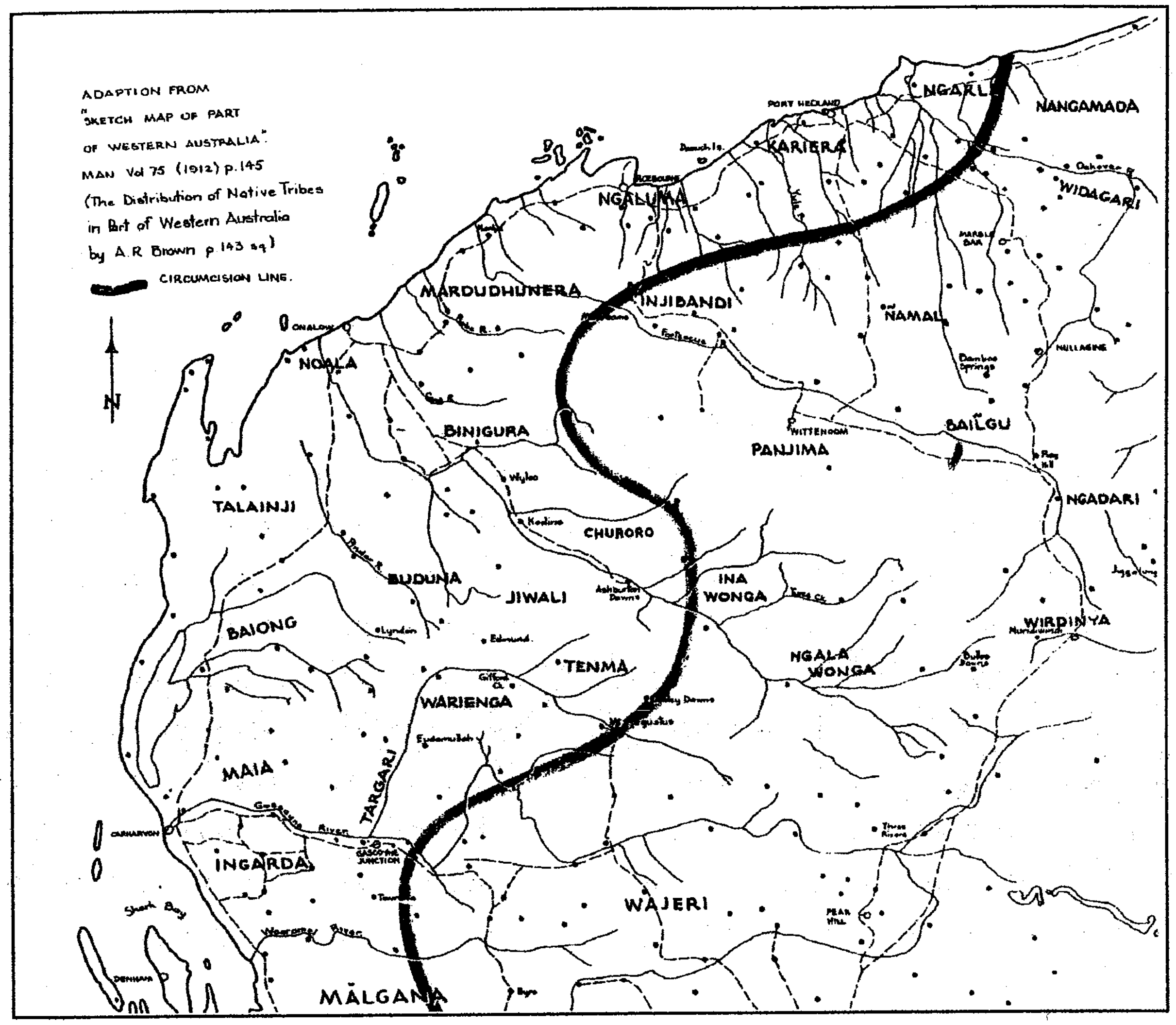


Figure 2.6 Connelly's (1932) map of inland Pilbara Aboriginal groups. From von Brandenstein (1967)

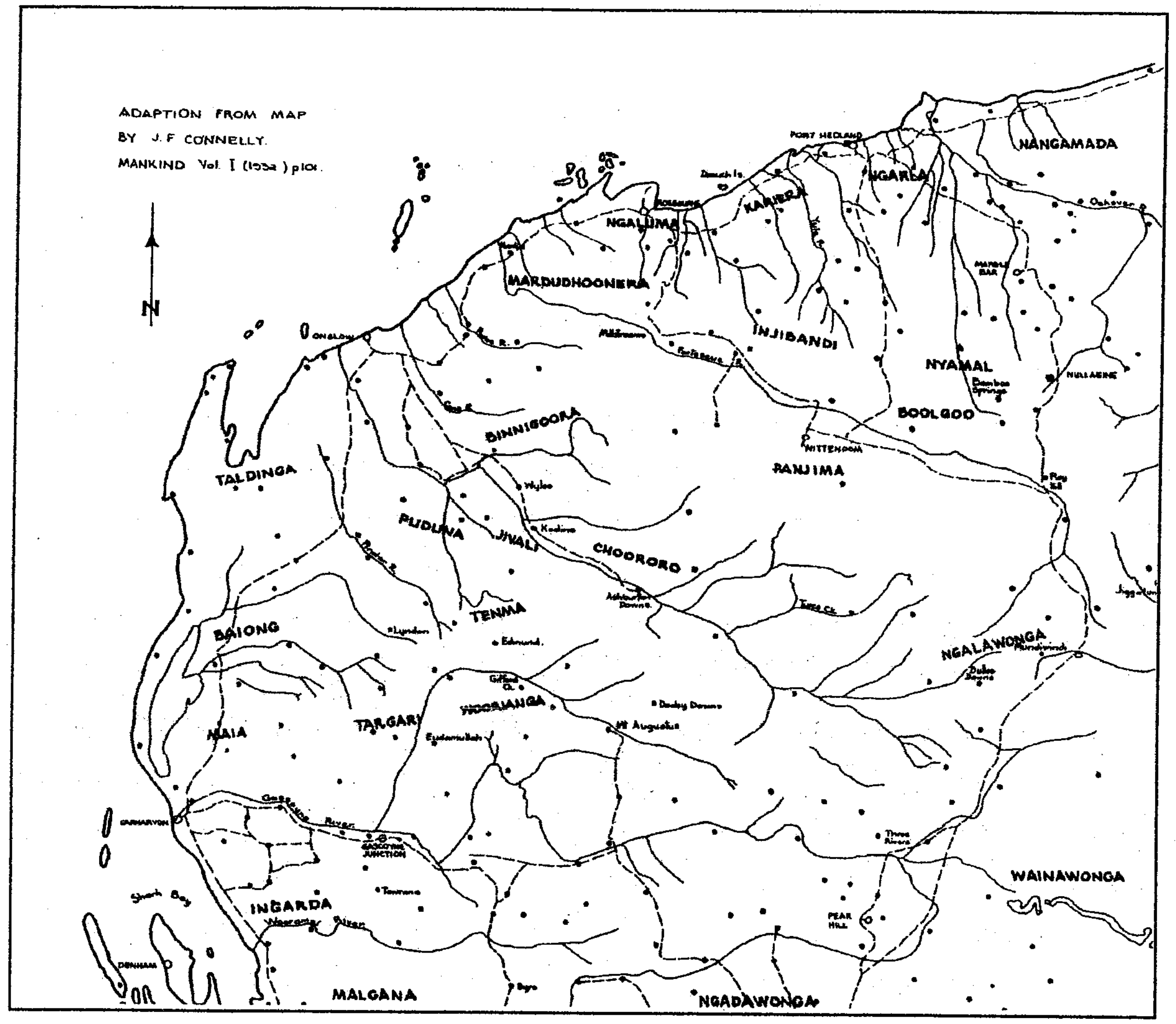


Figure 2.7 Tindale's (1940) map of inland Pilbara Aboriginal groups. From von Brandenstein (1967)

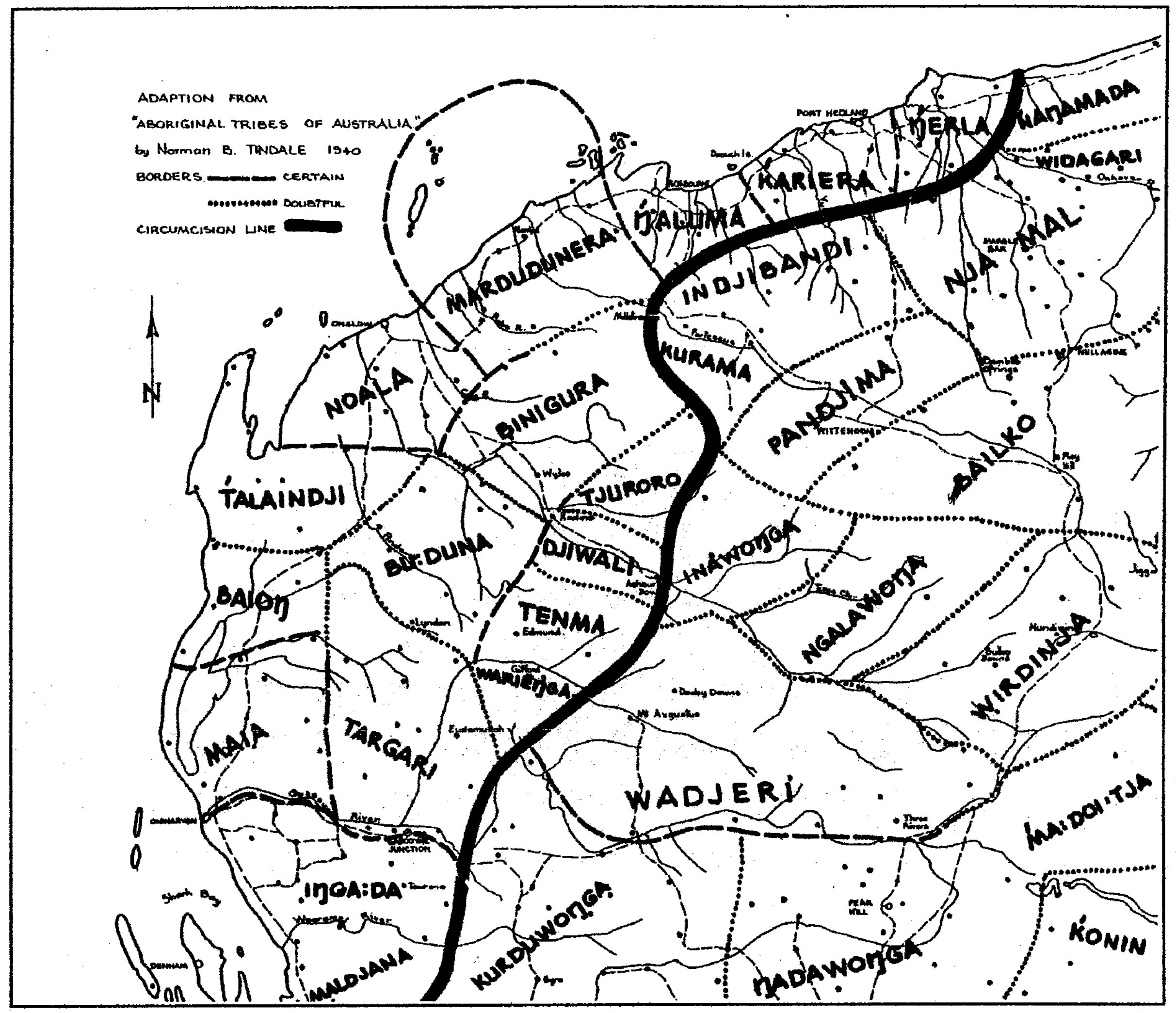
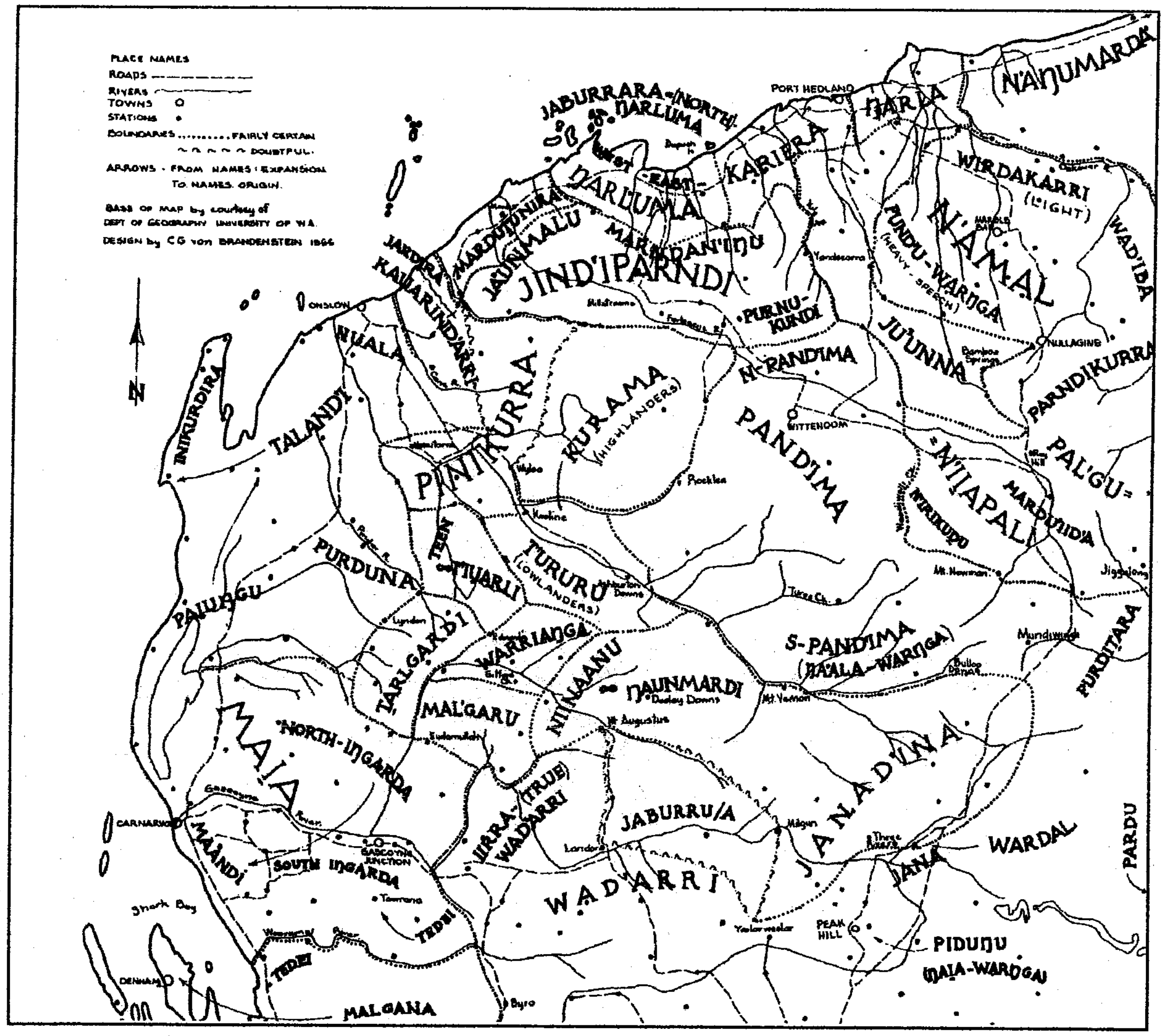


Figure 2.8 von Brandenstein's (1967) map of inland Pilbara Aboriginal groups.



Tindale (1974:225) writes that the Pandjima, under pressure from the Kuruma, moved eastward, pressuring the Niabali eastward. Clarke and Smith (1982b:6) write that the Pandjima and Niabali perceived their boundary along the Weeli Wolli Creek area as a shared location rather than a clear demarcation. The Niabali occupied the far northeast of the Hamersley Plateau and in about 1890 the pressure from the Pandjima in the west was joined by pressure from the Kartudjara to the east (Tindale 1974:253). The Pandjima also moved south, absorbing the neighbouring Mandara group, as did the Niabali, who also absorbed the saltmarsh exploiting Bailgu group. The Pandjima, Kuruma, Niabali, and Mandara groups practiced circumcision and subincision. Tindale (1974:247, 252) and Clarke and Smith (1982:6) write that by the mid-twentieth century the Mandara and Bailgu were no longer recognisable groups.

Circumcision and subincision was practised by the Inawongga group who were the southern neighbours of the Kuruma and Pandjima. According to Tindale (1974:241) the boundary of the Inawongga and their south-east neighbour, the Ngarlawongga, was closed and Inawongga people were not allowed to visit Tunnel Creek in Ngarlawongga territory. To the north of the Kuruma and Pandjima were the Indjibandi who practised circumcision but not subincision. Tindale (1974:242) writes that in recent times the Indjibandi began moving west, usurping the Jadira territory. The Kariara group claimed that the Indjibandi were inland Kariara until the adoption of circumcision rites by the Indjibandi caused enmity between the two (Tindale 1974:244).

A curious feature of the Indjibandi is that while they were apparently involved in the section and kinship systems of the inland Pilbara, data from gene surveys indicate that in recent pre-contact times they were genetically isolated from surrounding groups. Birdsell's (1976, 1993) studies of the frequencies of the Rhesus blood-group genes show that the Indjibandi had much higher frequencies of the R^z gene and lower frequencies of the R^o genes and leucocyte antigens than surrounding groups. The distribution of frequencies of the R^z gene indicates that a little gene flow occurred to groups south of the Indjibandi (Birdsell 1993:57). Measurements of dentition, morphology, metrical and indicial traits also show that differences existed between the Indjibandi and other inland Pilbara groups (Birdsell 1993).

These contrasts in gene frequencies indicate that recent cultural and biological processes had led the Indjibandi to marry with neighbouring groups much less frequently than other inland Pilbara groups. The presence of a genetic isolate such as the Indjibandi show that 'evolutionary events have a marked tendency to act upon tribes as individual units' rather than as regional populations in the inland Pilbara (Birdsell 1976:110). The Indjibandi adopted circumcision rites from their northeast neighbour, the Njamal group, in late pre-contact times. The Njamal were feared by the Kariara to the west, who seldom went beyond their boundary at the Turner River (Tindale 1974:244).

The non-circumcising groups to the west and north of the inland Pilbara include the Binigura, Talandji, Jadira, Noala, Ngaluma and Kariara. For non-circumcising groups male initiation involved binding the biceps with a tourniquet (Dench 1995, 2001, Brown 1913:167-174). An exception to the non-circumcising groups to the north and west are the Mardudunera, who range from the Dampier Archipelago to the foothills of the Hamersley Range. The Mardudunera, according to traditional narratives collected by Dench (1995, 2001), looked to the east for the origin of their law and sent young men to the Indjibandi and Kuruma for circumcision. The Mardudunera initiation process of bicep binding and the late pre-contact adoption of circumcision by the Indjibandi suggest that the eastern rites have gradually progressed westwards since before European contact.

Aboriginal groups in the inland Pilbara had either a four or two section system for classifying kin. There are local variations in the arrangement of the system across the inland Pilbara, and the southernmost groups appear to have less developed section system than the northern groups (Dench 2001, Tindale 1974). Amongst the northern groups Brown (1913) distinguished a variant of the Aranda type kinship system (four lines of descent and marriage dependent on cross-cousin links in the parents' generation). Groups in the southern Pilbara kinship systems were organised along another Aranda variant, called Talaindji by Brown (1913). Brown (1913) described the kinship system of the Mardudunira people on the northwest coast as Arandic, although Scheffler (1978) has argued that they used a Kariera type kinship system (two patri-matrilineal lines of descent ant the possibility of cross-cousin marriage).

According to Yengoyan (1968, 1976), section systems extend the spatial distribution of individual's relatives allowing related individuals and groups to exploit wider areas, especially in times of ecological stress. McKnight (1981) has criticised Yengoyan's conclusion that section systems confer survival value by showing that Yengoyan's method excluded groups in favourable environments that possess subsections or sections and groups in harsh environments that possess moieties only, or may even be classless. McKnight (1981) suggests that 'there can be no all-embracing explanation for their distribution', but I suggest that section systems may be adaptive because they provide structure to social relations to mediate conflict in very low *or high* population densities where fission is not always viable in solving disputes. Bowdler (1981:109-110) has proposed that section systems arrived in Australia as 'invisible luggage' along with the Australian Small Tool Tradition and that they were adaptive sub-systems that facilitated large ceremonial gatherings. McConvell (1985, 1996, 1997) attempts to provide chronological resolution to the appearance of section systems by using the technique of linguistic stratigraphy. According to this method, section systems such as the Kariera appeared in the late Holocene, while the Arandic system only arrived in northwest of Western Australia in the last 1000-2000 years (McConvell 1996:130, 1997:234).

Dench's (2001) undertook a comparative study of phonological innovations, morphophonemic alternations and casemarking patterns of Pilbara Aboriginal languages to investigate if there is any evidence for genetic or areal grouping. Dench (2001) concludes that diffusion of grammatical features has obscured genetic and areal groupings of languages in the Pilbara. According to Dench (2001) the evidence on linguistic systems of Aboriginal groups in the inland Pilbara indicates

> long and well established contact amongst groups in the region. Indeed, there are enough similarities that we cannot immediately establish any strong evidence that originally culturally distinct groups have come into contact, rather than that the diversity reflects a gradual differentiation as different cultural innovations have diffused into and across the area.

Dench (2001) suggests that the absence of distinct linguistic blocks in the Pilbara may result from a long period of equilibrium. Equilibrium does not mean stasis or homogeneity, but an ongoing ebb and flow of linguistic and cultural systems without directional change (Dixon 1997:68-72). The variation observed in Pilbara cultural patterns by Tindale may result from relatively recent low-level punctuations (instabilities created by fission or fusion of groups resulting from natural causes, material innovations or cultural transformations) that were preceded by a long period of equilibrium that has obscured deeper cultural and linguistic relationships (Dench 2001, Dixon 1997, 2001).

CONCLUSION

In this chapter I have investigated previously reported archaeological and ethnographic evidence from the inland Pilbara and surrounding regions to see how it answers the two questions I presented in chapter one. Below I present a summary of how previously reported archaeological and ethnographic evidence contributes to answering the two questions.

1. How did people in the inland Pilbara respond to the extreme environmental changes of the Last Glacial Maximum (LGM) at around 18,000 BP, and how and why does their response differ from people in surrounding areas?

Archaeological sites in the Kimberley, northwest coast and desert interior show abandonment or reduced intensity of occupation during the LGM. There are four sites relevant to the LGM question, Newman Orebody XXIX, Newman Rockshelter, Mesa J J24 and Malea. Evidence from the two Newman shelters has been argued both for and against LGM abandonment, but I argue that evidence from Newman Rockshelter, Mesa J J24 and Malea suggests abandonment or reduced frequency of occupation compared to pre-LGM and Holocene occupation. Previously reported evidence from the inland Pilbara and surrounding areas indicates that abandonment or reduction in frequency of site use was a regional response to LGM conditions. The signal of abandonment or reduced activity in the inland Pilbara sites may be because the sites are not close enough to the escarpment to readily access habitats favourable for LGM occupation.

2. What are the cultural, economic and demographic implications of the appearance of new stone artefact types and changes in the intensity of site use and the numbers of sites occupied during the middle and late Holocene?

Previously reported evidence from the inland Pilbara shows that new technological types first appear after 3700 BP, but only in small numbers at a few sites. It is not possible to convincingly show whether the new types indicate an economic change or a social change because of the small size of excavated assemblages and the lack of detailed technological analysis in some site reports. The timing of the earliest new types is similar to surrounding regions suggesting the new types were associated with multi-regional changes. The timing of the new types is similar to dates for the fluorescence of Pilbara rock art. Ethnographic evidence provides evidence of associations between new Holocene artefact types and gender relations and ritual activity. It is proposed here that the first appearance of the new artefact types in the inland Pilbara indicate the first appearance of systems of gender relations associated with these types in the ethnographic record. Grinding technology is currently dated to about 1600 BP in the inland Pilbara and ethnographic evidence suggests that grinding activity is related to systems of subsistence, ritual activity and gender relations, so the fluorescence of grinding may relate to the appearance or reorganisation of these systems.

Archaeological evidence from the desert interior suggests that the fluorescence of grinding technology is related to increases in the intensity of site occupation at 1400-600 BP. Previously reported radiocarbon dates from archaeological sites in the inland Pilbara indicates that occupation magnitude at sites increased at 2500-1500 BP and 0-600 BP. The inland Pilbara pattern of late Holocene site use differs from the uniform increase observed at sites in the desert interior because some sites in the inland Pilbara are abandoned after 3000 BP. Ethnographic information suggests that fission and fusion of groups was common in the inland Pilbara during recent pre-European contact times, and linguistic evidence also suggests that this is a relatively recent phenomenon. It is proposed here that the fission and fusion of groups may be linked to archaeological indicators of increased occupation magnitude in the inland Pilbara.

3. Methods

INTRODUCTION

Research summarised in the previous chapter has cast some light on the two questions of LGM occupation and Holocene changes in technology and population dynamics, but much ambiguity remains. This chapter describes the methods used in this project to answer these two questions. In this chapter I survey approaches to identifying changes in population dynamics, review the methods available for investigating changes in the timing, intensity and types of hunter-gatherer occupation in rockshelters and explain why I selected the methods I used. The timing of occupation is determined by creating chronological units based on similar sediment data and radiocarbon dates. Changes in the intensity and type of human occupation are determined using evidence from organic material, sediment data and stone artefacts.

It should be noted that my analysis was conducted on materials excavated by Lynda Strawbridge over ten years ago. During prolonged storage sediment samples may undergo physical and chemical changes. These changes mean that some of the sediment attributes measured during the course of this project differ from the same measurements taken in the field. I assume that the physical and chemical changes during storage were uniform throughout the sediment samples and focus on relative differences as indicators of significant differences between samples.

Review of approaches to identifying changes in population dynamics

Population dynamics can be literally restated as 'the forces of people'. I recognise three variables that influence the magnitude of population dynamics: (i) the *number of people* in a population, (i) the *type of activities* they engage in and (iii) the *intensity, or frequency and duration*, of their activities. The survival, identification and chronology of traces of activity in the archaeological record are further variables for consideration when reconstructing past changes in population dynamics. In this section I review previous work on investigating changes in the number of people in a population.

The use of counts of sites in a region as an indicator of relative population change has been a common and widespread practise amongst archaeologists around the world (Willey 1953, Binford 1968, Weiss 1978, Price 1981). In Australia archaeologists have argued that more sites equal more people throughout the continent, for example, Hughes and Lampert (1982) in southern coastal New South Wales, Ross (1981) in north-western Victoria, Lourandos (1977, 1983, 1985) and Williams (1985, 1987) in south-western Victoria, Stockton (1983) in northern Tasmania and Beaton (1985) in north Queensland.

The assumption behind the use of number of sites as an indicator of relative population is that more people require more separate living spaces. The reliability of this assumption was questioned by Binford (1983) who proposed an alternative explanation for changes in numbers of sites based on changes in subsistence strategies. Drawing on research into gatherer-hunter subsistence-settlement patterns and his ethnoarchaeological studies of the Nunamiut, Binford (1983) argued that gatherer-hunters worldwide exist on a continuum with foragers at one extreme and collectors at the other. Foragers are defined as people who exploit relatively homogeneous environments and moved themselves ('map on') to exploit resources dispersed throughout the landscape (Binford 1983). Collectors are defined as people who inhabit more heterogeneous and seasonal environments where resources were collected ('logistical') and brought back to a central base camp (Binford 1983).

According to Binford (1983) foragers that 'map on' to their resources generate two types of archaeological sites: 'residential bases' that are the loci of subsistence activities and where most of the processing, manufacturing and

maintenance activities take place and 'locations' where only extractive tasks are performed (Binford 1983). Typically, residential sites are the only remains of forager activity because extractive sites are ephemeral, often occupied for short periods and are only used once (Yellen 1977, Hayden 1978). On the other hand, collectors who consume resources logistically generate a diversity of archaeological sites (Chatters 1987). In addition to the residential site and the location, Binford (1978, 1983) argues that collectors create 'field camps', 'stations' and 'caches'. Binford (1983:343-7) defines a field camp as 'a temporary operational centre for a task group', a station as 'sites where special purpose task groups are localized when engaged in information gathering' and caches as 'temporary storage facilities'. In brief, more sites and a higher variety of site types are expected for collectors than foragers.

An important implication of Binford's forager-collector model is that an increase in the number of sites in a region can result from a shift in subsistence strategies between a foraging strategy and a collecting strategy, rather than an increase in population (Davidson 1990:44). However, Binford (1983:348-53) writes that two classes of variables condition the tendency of a population to be foragers or collectors; environmental conditions and population density. Binford (1983:353) suggests that groups switch to a logistical strategy in response to competition for access to similar resources under conditions of increased population density. Population pressure is an invisible force in Binford's model because it can drive the change from forager to collector, but evidence for population change is likely to be obscured by the increase in the number of sites resulting from transition to the logistical strategy.

Binford's model has been criticised by Wiessner (1982) who argued that he neglects the social aspects of hunter-gatherer adaptation. Wiessner (1982) proposes that many hunter-gatherer societies' strategies for the reduction of risk (defined as the probability of economic loss) influence social organization. In addition to Binford's forager-collector continuum, Weissner (1982) proposes another continuum. At one end of her continuum are hunter-gatherers who accept risk at the level of the local group, though pooling and widespread sharing of resources amongst families camped together. At the other end are societies in which risk is accepted at the level of the nuclear family, with fewer opportunities to use pooling to even out differential success at resource collection. Wiessner (1982:173-175) suggests that hunter-gatherers at different places on this spectrum will have differences in the numbers of sites used, internal site structure, distribution of faunal remains within a site, intersite variability, exchange and stylistic variation in artefacts.

Wiessner (1982:176) concludes that hunter-gatherer organisational strategies cannot be exclusively defined in terms of organization around resources, but must include strategies 'used in organization around other persons in the social relations of production'. The relevance of Wiessner's (1982) comment to the relationship between site numbers and population size is that changes in social strategies can change the number of sites independent of a population change. For example, the Kung are annually faced with the most abundant resources located far from water sources and instead of storing mongongo nuts they solve this problem by visiting friends and relatives in other areas or falling back onto secondary resources, generating a greater number and diversity of archaeological sites (Wiessner 1980). Kung groups have organised social ties that allow them to 'map onto' the resources of other groups at times when resources in their area are low and resources in other areas are more abundant (Wienssner 1982:176).

In summary, numbers of sites alone are not reliable measures of population changes because changes in site numbers can result from changes in subsistence and social strategies. Non-human factors such as geomorphological conditions can also influence site preservation and numbers independent of population changes (Rowland 1989, Ross 1985). To overcome these cultural and non-cultural variables that influence the number of sites, archaeologists also need to investigate changes in the discard rates of cultural material and sediments at individual sites to identify changes in population sizes.

Hughes and others (1977, Hughes and Sullivan 1981, Hughes and Lampert 1982) have argued that the accumulation of roof fall, windblown sediments and alluvium in archaeological sites reflects human use. The underlying assumption is that frequency of use determines rate of sediment accumulation (Hughes and Lampert 1982:19). If site use is infrequent and sediment accumulation is very slow then organic materials are less likely to be preserved and human deposition contexts are more likely to be disturbed by natural processes. If site use increases then the probability of an archaeologically visible deposit forming also increases.

In addition to increases in rates of sedimentation, Hughes and others (1977, Hughes and Djohadze 1980, Hughes and Lampert 1982, Ferguson 1985, O'Connor *et al.* 1993) interpret numbers of stone artefacts as indicators of population size. Hughes and Lampert (1982:25) explain that they only quantified formal tools because they are linked to extractive tasks such as subsistence, while unmodified flakes, broken flakes and angular fragments are linked to maintenance activity that may not be related to the number of people at the site. Hughes and Lampert (1982:26) interpret increases in roof fall, windblown sand, alluvium and stone implements after 5000 BP at Burrill Lake Shelter, Currarong Shelters 1 and 2 Sassafras Shelter 1 and Bass Point in southern coastal New South Wales as a result of population increases rather than external geomorphological processes or changes in artefact technology.

Hiscock (1981) has criticised Hughes and Lampert's (1982) use of stone implement as a measure of intensity of site use and argues that changes in implement discard rates will be affected by changes in the use of the site, changes in raw material use as well as changes in occupation intensity. Hiscock (1981) suggests that a more convincing approach to identifying changes in site use and occupation intensity should consider a combination of stone artefact traits relevant to intensity of subsistence activities such as number of utilised edges and amount and types of secondary working.

Rates of artefact discard and sedimentation have been related to population changes in the Northern Territory (David *et al.* 1994, 1990), Queensland (David and Chant 1995, David 1991) and the Kimberley (O'Connor 1999). In the Northern Territory increases in the deposition rates of stone artefacts (formal tools and other pieces), ochre, charcoal, bone, mussel shell, eggshell and 'ochred cortex' at 1400-900 years ago have been linked to the appearance or intensification of rock painting activity (David *et al.* 1994, 1990). The increases in quantities of rock painting activity, identified by the ochre in the deposit, and cultural materials at Yiwarlarlay 1, Delamere 3, Mennge-ya and Garnawrla 1 are believed to be related to new strategies of territorial behaviour occurring 'in response to population increases and/or changes in intensities of inter-personal relations' (David *et al.* 1994:250).

Similar arguments about sedimentation rates, rock painting and population change have been advanced for northern Queensland (David and Chant 1995, David 1991). David (David and Chant 1995:514), who excavated and analysed material from nine sites, proposes that increases at in the deposition rates of flaked stone artefacts, non-flaked stone, mussel shell, egg shell, ochre, sediment, burnt earth and charcoal at around 3000 BP are related to a 'closure of socio-cultural systems in association with an increase in size and density (that is, overall demographic changes)'. David used depth-age curves to interpolate and extrapolate changes in discard rates of sediments and cultural material. Depth-age curves are particularly important for David because the ochre deposition rates are deduced from them and linked to the intensification and diversification of rock painting. David uses the depth-age curves to show that increases in the deposition of sediments and cultural materials occur at a similar time as increases in the number of styles and motifs in the rock paintings. David (1991:54-55) argues that these changes are indicators of re-structuring of land ownership and interacting populations resulting from population increase.

Davidson (1997b) has criticised David's (David and Chant 1995) use of age-depth curves and proposes that the assumptions involved in using age-depth curves determine the interpretations that can be made from the archaeological data. A larger number of dates and an analysis of sediment formation processes could provide a more convincing picture of changes in the rock paintings and rates of sediment and cultural material deposition. Davidson (1997b) also writes that the brevity of David's stone artefact analysis means that he cannot be certain that changes in artefact numbers result from population changes or changes in the function of the site.

Hiscock's (1984, 1988) analysis of cultural material excavated from Colless Creek Cave, northwest Queensland, combines an analysis of discard rates with a detailed analysis of changes artefact technology. Hiscock (1984) proposes seven testable explanations for changes in the discard rates of stone artefacts, which I have summarised in table 3.1.

Table 3.1 Summary of Hiscock's (1984) seven testable explanations for changes in rates of cultural material discard and sedimentation.

explanation for change		test
1	errors and bias in excavation and analysis methods	reanalysis of excavated material, more excavation
2	post-depositional modification	analysis of stone artefact conjoin patterns, analysis of trampling and heat treatment of stone artefacts, sediment analysis, more radiocarbon dates
3	spatial change in location of discard areas	more excavation at the same site
4	changes in the system of artefact manufacture and use	technological analysis of stone artefacts
5	change in site use	analyse open sites from the same period, analyse changes in faunal remains
6	environmental stress or population pressure	find and analyse a number of sites in the region; sites in one areas should show increases use while at the same time sites in another area should show decrease in use.
7	population increase in the region	find and analyse a number of sites in the region; all sites should show an increase in use at the same time.

In his analysis of material excavated from Colless Creek Cave and Louis Creek Cave, north-west Queensland, Hiscock (1984, 1988:177-228) tests the seven hypotheses by measuring, amongst other things, changes in a number of variables related to artefact production including patterns of flake breakage, heating of stone, knapping techniques, raw material, decortication procedures, amount of applied force, location of force application and length of reduction sequence. A peak in stone artefact discard occurs at Colless Creek Cave during the LGM and Hiscock (1988:219) interprets this as a result of territorial restriction and a change in artefact technology related to raw material procurement because the peak coincides with a high proportion of artefacts made from locally available raw materials. Hiscock (1988:228) proposes that economic reorganisation to cope with environmental stress is the best explanation for changes at the two sites and eschews explanations involving changes in population size. Hiscock's study indicates that analysis of stone artefact technology and raw material procurement can provide alternative explanations to population increase for peaks in artefact discard.

The above review of previous approaches to identifying changes in population dynamics shows that there are methods for convincingly measuring changes in population size, the first of the three variables that influence population dynamics. Population size is difficult to measure directly from the archaeological record because of the lack of appropriate evidence such as dwelling sizes, skeletal and genetic evidence (Hassan 1981). Determining changes in population size using numbers of sites is inappropriate because numbers of sites are sensitive to a range of other variables, such as subsistence strategies and social organization. This discussion of previous approaches to identifying population changes in the archaeological record shows that several criteria need to be satisfied before arguments about population can be made. These criteria are similar to those recently identified by Dortch and Smith (2001) in their discussion of demographic modelling in the southwest of Western Australia. Dortch and Smith (2001:41) write that population change is indicated when rates of deposition of archaeological material (fauna, charcoal, ochre, stone artefacts) and non-archaeological material (sand, silt, sediment, rubble from rockshelter walls and roof) change at the same time and in the same direction in multiple sites throughout a region. In assembling these multiple strands of evidence, attention must be given to past physical conditions, site-specific depositional processes and post-depositional processes (Dortch and Smith 2001:41).

The rest of this chapter is devoted to describing the methods I used to identify changes in the second and third variables of population dynamics, types of activities and intensity (or duration and frequency) of activities. Changes in the types of activities can be determined by analysis of changes in artefact technology and other cultural and non-cultural remains. Changes in the intensity of activities can be discerned when there is an increase or decrease in multiple classes of archaeological material at multiple sites and no change in the types of activities. In taking this multivariate approach I hope to assemble a cumulative weight of evidence from multiple strands of data that is 'rationally decisive' (Bernstein 1983:74, cf. Wylie 1989) on the question of changes in population dynamics.

Investigating the timing of human occupation

The first stages in identifying changes in cultural systems and population dynamics are to establish the time periods that the sites represent and establish when changes in the cultural sequence occur. Analysis of sedimentary data and radiocarbon dates allows the deposit to be divided into normative chronological units to detect change in human activities over time.

Excavation

The four sites examined in this project, Marillana A, Marillana B, Cleft Rock Shelter and Milly's Cave, were excavated between 1988 and 1993 by Lynda Strawbridge and her assistants. Information on excavation procedures comes from Strawbridge's notes and discussions I had with her over the course of my project. Excavations were undertaken in arbitrary spits (or excavation units) of 3-5 centimetres. Each excavation unit in each 1 m^2 was excavated in four quadrants of 50 x 50 cm that were recorded and bagged individually. Excavation procedures involved loosening the deposit with a bricklayer's pointing trowel, scraping it into hand-shovels and putting it into plastic buckets. The mass of each bucket-load of deposit was recorded after which the deposit was passed through a nest of 6 mm and 3 mm sieves. Depths of the four corners and centre of each excavated unit were recorded using a dumpy level and staff.

Identifying stratigraphic units

For my analysis I grouped excavation units with similar sedimentary properties into stratigraphic units. I grouped excavation units into stratigraphic units because changes in human behaviour and environmental processes are likely to be associated with changes in sediments attributes (Hassan 1978, Stein 1987). While sacrificing resolution, the grouping of excavation units into stratigraphic units increases the sample sizes of cultural materials so that statistical procedures can be used and more convincing comparisons can be made. Comparisons between individual excavation units can be risky because it might result in comparing single events to each other, which would provide very short-term temporal resolution at the expense of the longer-term trends that are of interest here. The attributes measured include particle size, pH and sediment colour combined with descriptions and drawings of sediments recorded during the excavation of each site.

The aim of the particle size analysis is to identify and describe differences in source materials and processes of transport, erosion and deposition for each spit (Gale and Hoare 1991:65-71). Particle size analysis was undertaken using a nest of six Endecott sieves from size -2 ϕ to 4 ϕ at 1 ϕ intervals sieved for fifteen minutes on a Sieveforce vertical shaker (Gale and Hoare 1991:82-7). The entire field sample was dry-sieved through the -2 ϕ and -1 ϕ sieves and then a 20 g oven dried sub-sample was dry-sieved through the 0 ϕ to 4 ϕ sieves. Mean, standard deviation, skewness and kurtosis statistics were calculated using GRADISTAT software for Microsoft Excel (Blott and Pye 2001).

I attempted to measure the proportions of silt and clay in the sediments by pipette analysis (Gale and Hoare 1991:87-94), but was unsuccessful, even with the addition of a dispersant (sodium hexametaphosphate). The sediments flocculated and settled well before the clay and silt fractions should have. Repeated washing of the sediments with deionised water suggested that the rapid settling was in part caused by high concentrations of soluble salts that made the dispersant ineffective. Webb (1992:47) observed a similar problem of rapid settling in her hydrometer analysis of sediments from rockshelters in the Murchison, Western Australia. The sediments analysed by Webb (1992:47) are from iron-rich rock, similar to inland Pilbara formations, and she writes that the sediments settle quickly because the iron-rich particles have a density much greater than quartz (2650 kg m^{-3}). The density of quartz is the assumed density of particles analysed using pipette and hydrometer analysis and if the actual density differs greatly from that of quartz, then the techniques dependent on settling times of particles do not work (Gale and Hoare 1991:88). The limitations of time prevented me from investigating the problems of analysing silt and clay or developing new methods to determine clay and silt proportions.

The acidity or alkalinity of sediments is measured by pH, which is an expression of the concentration of hydrogen ions in solution. pH values can reflect very localised conditions and vary within a spit (Courty *et al.* 1989:20). In sediments that have formed over a long period the pH is likely to have changed since the formation of the of the sediment and pH should be seen as an index of pedogenesis (soil formation) and post-formational modification (Gale and Hoare 1991:275). Although the sensitivity of pH to post-formational changes means that it is of limited use in identifying anthrosols, pH is relevant for understanding the behaviour of other chemical indicators such as phosphorus and for describing preservation conditions (Stein 1987:371-372, Proudfoot 1976, Courty *et al.* 1989:20).

Sediment pH may be related to changes in the amounts and preservation of organic material discarded by people during occupation (Stein 1987:372), but its

main use here is as another measure to group similar spits into stratigraphic units. Conditions of preservation are indicated by pH, with alkaline sediments favourable for the preservation of organic materials. Measurements of pH were taken in the field by Strawbridge using colorimetric techniques (indicator solutions) but these are often neither accurate (the degree to which the measurement approximates the true value) nor precise (repeatable) (Gale and Hoare 1991:275). Following Alymore *et al.* (1997) I measured pH in a 1:5 sediment to de-ionised water solution (tumbled for 24 hours and centrifuged for 30 minutes at 2000 rpm) with a Cyberscan electrometric pH meter calibrated using buffer solutions of pH 4, pH 7 and pH 10.

Sediment colour provides another variable for grouping similar excavation units because it is sensitive to differences between sediments that result from different formation conditions. Sediment colour was recorded in the field but field measurements are often inaccurate and imprecise because of varying viewing conditions, moisture content, sample freshness and variation in colour perception by different observers (Gale and Hoare 1991:158). I recorded sediment colour for each spit using the *Munsell soil colour charts* with 10 g oven dried sample in indirect sunlight.

To group excavation units into stratigraphic units I first grouped them based on similarities in particle size distributions (as an index of gross differences) and then used pH and colour (as indices of more subtle differences) to see if the grouping based on particle size could be subdivided.

Dating the sequences

With radiocarbon dates the temporal order of stratigraphic units and rates of sedimentation can be determined. Radiocarbon dates were determined from charcoal removed during excavations. Dates obtained by Lynda Strawbridge were on charcoal samples taken *in situ* while dates obtained for this project were on charcoal collected from sieves or bulk samples. All dates from the four sites analysed in this thesis are from the University of Waikato Radiocarbon Dating Laboratory, New Zealand and are expressed as uncalibrated dates (conventional radiocarbon ages or CRA) with one standard error. It should be noted that chronological resolution at the four sites examined for this project was constrained by limitations in time and money.

INVESTIGATING CHANGES IN THE INTENSITY AND TYPE OF HUMAN OCCUPATION

Analysis of sedimentary data, organic material and stone artefacts allows relative differences in the intensity and type of occupation intensity to be described between different stratigraphic units. Individually, the variables discussed here are not unambiguous indicators of changes in the type and intensity of human occupation. Only when there are contemporaneous changes in multiple variables at a range of sites are the minimum criteria for postulating significant changes in human occupation satisfied (Dortch and Smith 2001, David and Chant 1995:376-380).

Quantities of the variables under consideration here are presented here as a unit measure (i.e. grams of charcoal or numbers of artefacts) per cubic metre for each excavation unit. I chose this approach because raw numbers per excavation unit does not account for variation in the depths of the excavation units. Although a potentially more accurate approach, quantities per time period were not used because the small number of dates from each site would obscure changes occurring in long undated periods. I have preferred excavation unit volume rather than mass of sediment in an excavation unit because volume is independent of other measures of occupation intensity, such as sedimentation rates and compaction, and sediment mass per excavation unit was not recorded for all excavated units.

Organic material

The presence of organic material at archaeological sites has been used as a signature of human occupation. The assumption here is that as people occupy a site, organic matter accumulates on the living floor in the form of discarded food refuse, and the debris of fire-building, shelter construction and tool manufacture (Stein 1992). These activities enrich the soil with organic matter which, depending on the extent of decay, is then detectable in excavated sediments. Excavated assemblages from the inland Pilbara typically have very small amounts of organic material (Brown 1987:42, 54). I identified faunal material using a reference collection at the University of Western Australia. The faunal material was quantified using NISP (Numbers of Individual Specimens, also known as NR, number of remains or TNF, total number of fragments) and mass (Reitz and Wing 1999:156, 191-202). The highly fragmented nature of the

faunal remains prevented counts of numbers of individual animals such as MNI (Minimum Numbers of Individuals).

I divided non-bone organic material into two categories: sedimentary organic material and soil organic material (Stein 1992). These materials reflect a combination of non-cultural processes and human use of the site. The mass of non-bone sedimentary organic material such as grass, seeds, leaves, roots and scats was recorded for each spit but no identification was attempted. The mass of charcoal for each spit was recorded as an indicator of firing frequency and duration. The species of flora represented by the charcoal were not identified due to limitations of time, but the results of such a study would be useful for reconstructing past climates in the inland Pilbara.

Soil organic matter is organic matter that has weathered and caused an *in situ* alteration of the soil associated with the organic material (Stein 1992:196). To measure soil organic matter percentage per excavation unit I used a low-temperature ignition method. Although a variety of wet and dry oxidation techniques exist for determining soil plant organic content (Nelson and Sommers 1982), they tend to give inconsistent results when applied to different materials (Gale and Hoare 1991:262). Davies (1974) found that ignition of sediments at 430°C for 24 hours overcame the problem of loss of mass due to decomposition of carbonates and errors from partial dehydration of minerals common at higher temperatures. After Davies (1974) I heated 10 g of oven-dried sediment from each spit for 24 hours at 430°C in a small chamber furnace. Percentage soil organic matter was calculated on the difference in sediment mass before and after ignition.

Soluble salt concentration

Concentrations of soluble salts in sediments can increase with increased firing activity as ash contains the salts in the combusted organic material (Gilkes pers. comm. 2002). Soluble salts can concentrations can also very depending on erosion and the source of the sediments (Courty *et al.* 1989:20-21). Following Alymore *et al.* (1997) I measured soluble salt concentration in a 1:5 sediment to de-ionised water solution (tumbled for 24 hours and centrifuged for 30 minutes at 2000 rpm) with a Cyberscan electrometric conductivity meter calibrated to 1413 $\mu S\ cm^{-1}$.

Total phosphorus, carbon and nitrogen concentrations in sediments at Marillana A

During the analysis of artefacts from the sites I noticed that the artefact sequence at one of the sites, Marillana A, suggested that the site was only intensively occupied after a roof-fall event at about 13,000 BP, with only a few artefacts deposited in the 47 cm (25 excavation units or spits) between about 13,000 BP and bedrock. This pattern is different from the other three shelters where artefact discard is continuous from the surface to bedrock. I wanted to know how changes in artefact discard at Marillana A related to the human use of the shelter so I analysed the sediments for changes in site function and occupation intensity. I analysed phosphorus, carbon and nitrogen concentrations at Marillana A to investigate whether a change in artefact discard rate indicated a change in intensity of site use or whether it reflected a change in the kinds of activities carried out in the rockshelters (for example, stone artefact manufacture compared to woodworking or non-resource extraction and consumption activities such as ceremonies).

The theory behind phosphorus, carbon and nitrogen concentrations as indicators of human occupation is that the surface deposition of organic matter, which contains these elements, increases during human occupation (Wells *et al.* 2000, Schlezinger and Howes 2000). Phosphorus is significant because while carbon and nitrogen can be transformed into inorganic forms that are not bound to the soil (for example, CO_2 for carbon and ammonium nitrate and N_2 for nitrogen), phosphorus is rapidly fixed by naturally occurring compounds to the soil and tends to remain stable in soils for very long periods with negligible horizontal and vertical migration and no gaseous escape (Wells *et al.* 2000, Schlezinger and Howes 2000, Leonardi *et al.* 1999, Skinner 1986:51). Phosphorus becomes enriched in the soil relative to carbon and nitrogen as organic matters decay and carbon and nitrogen compounds leave the soil. I measured carbon and nitrogen concentrations as indicators of the residual organic matter.

Phosphorus is one of the most widely used chemical markers amongst archaeologists in recent decades. It has been successfully employed to determine site occupation on temporal (Parnell *et al.* 2002, Schlezinger and Howes 2000, Lillios 1992, Skinner 1986, Ahler 1973, Cook and Heizer 1965) and

spatial (Wells *et al.* 2000, James 2000, Cavanagh 1988, Pouge 1988, Lippi 1988, Williams 1988, Sandor *et al.* 1986, Woods 1984, Conway 1983, Eidt 1977) scales at historic and prehistoric sites. In Australian archaeology phosphorus analysis has only previously been applied, so far as I am aware, in a spatial study of earth mounds in central south-western Victoria (Williams 1988). Phosphorus concentrations in archaeological sites have been determined using a variety of techniques including ignition methods (Schlezinger and Howes 2000), acid extraction colorimetry (Parnell *et al.* 2002, Wells *et al.* 2000, Leonardi *et al.* 1999, James 1999, Farswan and Nautiyal 1997, Ahler 1973, Eidt 1973), inductively coupled plasma-mass spectrometry (ICP-MS) (Entwhistle and Abrahams 1997, Entwhistle *et al.* 1998) and inductively coupled plasma-atomic emission spectrometry (ICP-AES) (Middleton and Price 1996).

I chose to use X-ray fluorescence (XRF) for quantitative analysis of phosphorus in archaeological sediments at Marillana A. Ignition and acid extraction colorimetry were not appropriate because quantities of phosphorus in Pilbara soils, as measured by Bentley *et al.* (1999), are below the detection limit of these methods. I did not use ICP-MS because the determination of phosphorus using this technique is problematic. Entwhistle and Abrahams (1997:411) found that monoisotopic ^{31}P suffers spectral overlaps from $^{14}N^{16}O^{1}H$ and potentially from $^{14}N^{16}O$ and O_2. To compensate for these problems Entwhistle and Abrahams (1997:411) determined phosphorus using ICP-MS in a fully quantitative mode that is more precise but not practical on economic grounds because of the greater demand on time and consumables. Indeed, Entwhistle and Abrahams (1997:411) now use cheaper colorimetric techniques rather than ICP-MS for determining phosphorus concentrations.

Although XRF is frequently used for sourcing archaeological obsidian, glass ceramic and metal (eg Hughes 1986, Henderson 1989, Sheridan 1989, Craddock 1989) it has never been used, so far as I am aware, in the analysis of archaeological sediments. XRF is an attractive technique because it is accurate, relatively cheap, easy to use, has short processing times and very low detection levels for total phosphorus and a range of other elements. The fundamental principle behind XRF is that when electrons of a particular element are excited by x-rays they emit or *fluoresce* a spectrum of x-rays that is specific to that element (Norrish and Chappell 1977, Jenkins 1988, Tertian and Claisse 1982). Following Norrish and Chappell (1977), and with the assistance of University of

Western Australia Department of Soil Science and Plant Nutrition analytical chemist Michael Smirk, I prepared the sediment samples by combining 0.007±0.0005 g of finely ground sediment with 7±0.0005 g of x-ray flux (lithium tetraborate and lanthanum oxide) and heating at 1050°C in a muffle furnace. After 45 minutes in the furnace the molten sediment-flux mixture was poured into a platinum bead mould and left to cool. The fusion beads were analysed using a fully automated Phillips PW1400/00 sequential x-ray spectroscope with a PW1730/10 constant potential x-ray generator calibrated using OREAS 42p, quartz and titanium dioxide standards. The machine was controlled by the Phillips X40 programme for MS DOS which also calculated the total elemental concentrations.

Total carbon and nitrogen concentrations were determined using the computer controlled LECO CHN 1000 high frequency induction furnace. The furnace converts the carbon (including carbon in carbonates) and nitrogen present in the sediment to gaseous form. Carbon (CO_2) is measured by infrared absorption and nitrogen (N_2) by thermal conductivity. A calibration curve of 10% EDTA was established before sediment samples of 350 mg each were analysed. Petra's Standard Soil was used as a standard. The total phosphorus, carbon and nitrogen analyses were undertaken at the University of Western Australia Department of Soil Science and Plant Nutrition with the assistance of analytical chemist Michael Smirk.

Magnetic susceptibility of sediments at Marillana A and Cleft Rock Shelter

I measured the magnetic susceptibility of the sediments at Marillana A and Cleft Rock Shelter to measure the intensity of firing in each spit. The purpose of this analysis was to try and discern between periods characterised by long and short visits. I analysed the magnetic susceptibility of sediments from Marillana A and Cleft Rock Shelter because they have long records of human occupation and more complete samples of sediments compared to the other two sites, Milly's Cave (only a few sediment samples available) and Marillana B (brief record of occupation). I expected periods of longer occupation to be characterised by sediments with high magnetic susceptibility because of the frequent firing of sediments in hearths. Conversely, I expected brief occupation episodes to be characterised by sediments with low magnetic susceptibility because the sediments were not frequently fired and probably not in the same

place each time. Like XRF, magnetic susceptibility is a technique has not been widely used in Australia, and I was interested to see how useful it is as a measure of human occupation intensity in the inland Pilbara.

Magnetic susceptibility measures the extent to which the sediments become magnetised when exposed to a magnetic field. Magnetic susceptibility analysis has been used by archaeologists over spatial (Ellwood *et al.* 1994) and temporal (Cotter *et al.* 2001, Ellwood *et al.* 1995, Ellwood *et al.* 1997, Bellomo 1993) scales at archaeological sites and on archaeological objects (Jordanova *et al.* 2001). Changes in magnetic susceptibility of sediments occur when magnetic grains in become concentrated or diluted through the addition or removal of materials and through transformation of minerals (Gale and Hoare 1991:211). Transformation of minerals from weakly susceptible minerals to strongly susceptible minerals can occur by weathering, pedogenesis, bacterial respiration, chemical reduction during organic matter decay and chemical oxidation during firing (Gale and Hoare 1991:211-5, Singer *et al.* 1996).

As the levels of organic matter in inland Pilbara rockshelters are typically very low below the surface, I considered that weathering, pedogenesis and firing would be the most significant sources of enhanced magnetic susceptibility. Pilbara soils are rich in iron, mainly in the form of haematite and goethite (Trendall 1975). These minerals are antiferromagnetic, meaning that they do not possess spontaneous magnetisation and their mass susceptibilities are very low (Gale and Hoare 1991:203). Haematite in soils is converted to magnetite when heated in a reducing atmosphere and magnetite is converted to maghemite during cooling in an oxidising atmosphere (Le Borgne 1960, Longworth *et al.* 1979, Thomson and Oldfield 1986:119). Magnetite and maghemite are ferrimagnetic, meaning that they possess a spontaneous magnetisation and have mass susceptibilities two to three orders of magnitude greater than haematite (Gale and Hoare 1991:203). Given the high concentration of haematite in Pilbara soils, I expected that heating of the sediments by hearth fires and bush fires should produce clearly detectible changes in the magnetic susceptibility of the sediments. Other indices of human occupation can then be used to discriminate between natural and cultural firing episodes.

I conducted the magnetic susceptibility analysis using the Bartington MS2 susceptibility meter and Bartington MS2B 36 mm internal diameter dual frequency sensor according to the procedure in Gale and Hoare (1991:221-226). Sediment samples were taken from the <-1ϕ fraction and analysed in 6 cm^3 plastic cubes at normal sensitivity. The analysis was undertaken at the University of Western Australia Tectonics Special Research Centre Palaeomagnetics Laboratory with the assistance of Zheng Xiang Li.

Stone artefact analysis

The aims of my stone artefact analysis were to provide another approach to determining changes in the relative intensity of the occupation between stratigraphic units and determine changes in the types of activities carried out at the rockshelters between stratigraphic units.

After Hiscock (1984, 1988:179-184) I considered five possible interpretations of changes in rates of artefact discard: methodological error, post-depositional modification, change in artefact technology, change in site function and change in shelter use. The variables I am able to test in this project are post-depositional modification, changes in the system of artefact manufacture and changes shelter use. I am not able to test for systematic recovery errors during excavation or spatial change in the location of discard areas within the cave because I am analysing material excavated over ten years ago and was not able to undertake further excavation because of constraints of time. Constraints of time and money prevent me from testing for systematic errors in radiocarbon dates and artefact identification and measurement. I minimised artefact analysis error by analysing all the artefacts myself using the same equipment and the same procedures.

Post-depositional change

Post-depositional change is a possible explanation for changes in artefact numbers as breakages can inflate numbers and vertical movement of artefacts can obscure the original discard behaviours. The density of sediments and the slow rates of sedimentation at inland Pilbara rockshelters suggest that vertical displacement is infrequent (Brown 1987:40-1). Even so, I used conjoins of stone artefacts as indicators of vertical mobility (Jodry 1992, Grimm and Koetje 1992). Conjoined artefacts occurring in more than one spit indicates high vertical mobility, while conjoins restricted to one spit suggest limited mobility and high

stratigraphic integrity. Conjoins were identified in the process of identifying, counting and measuring artefacts.

Artefact breakage was measured using the Sullivan-Rosen typological system (Sullivan and Rosen 1985). Although proposed as a system for identifying technological processes in stone artefact assemblages in the United States of America (Sullivan and Rozen 1985:755), recent experimental studies involving north American assemblages have shown that the Sullivan-Rozen typology produces repeatable results (Prentiss 1998) but cannot distinguish between different technological processes (Prentiss 1998, Austin 1999, Amick and Maulden 1997, Morrow 1997, Bradbury and Carr 1995, Kuijt *et al.* 1995, Baulmer and Downum 1989, Prentiss and Romanski 1989). While experimental studies of the Sullivan-Rozen typology show that it is not a good indicator of technological change, the typology has been shown to be a useful measure of breakage patterns (Odell 2000:290-292, 311, 313).

Following the Sullivan-Rozen typology I classified stone artefacts into four mutually exclusive categories based on the presence or absence of a single interior surface, point of applied force and intact margins (Sullivan and Rozen 1985:758-9). The single interior surface is the ventral side of a stone artefact and is identified by ripple marks, force lines or a bulb of percussion (Sullivan and Rozen 1985:758). If there are multiple bulbs of percussion (for example, bipolar flakes), force lines in more than one direction or no sign of ripple marks, force lines or a bulb of percussion, then a single interior surface cannot be determined (Sullivan and Rozen 1985:758). The Sullivan-Rozen typology does not include bipolar flakes, but as no bipolar flakes were identified in the assemblages it was not necessary to change the typology. On stone artefacts with an intact striking platform, the point of applied force is where the bulb of percussion intersects the striking platform (Sullivan and Rozen 1985:758). For fragmentary striking platforms the point of applied force is indicated by the origin of force line radiation (Sullivan and Rozen 1985:758). When a stone artefact has no striking platform, or when there is no single interior surface, the point of applied force is absent. Margins are intact when the distal end has a complete or partial hinge or feather termination. Margins are not intact when the striking platform is incomplete and lateral breaks prevent accurate width measurements (Sullivan and Rozen 1985:759). Margins are not considered for stone artefacts without a single interior surface and point of applied force.

I have departed from the Sullivan-Rozen typology by discerning between breaks that interrupt the width dimension (longitudinal broken flake) and breaks that interrupt the length dimension (transverse broken flake). I distinguish between the two types of broken flake because they preserve different types of information about site formation processes and technology. Experimental studies by Prentiss and Romanski (1989) and Hiscock (1985) have shown that trampling of stone artefact assemblages produces transverse broken flakes. Longitudinal broken flakes are associated with the mechanical failure of some raw materials in the production of small complete flakes (Sullivan and Rozen 1985:769).

Using the attributes of single interior surface, point of applied force and margins I classified each stone artefact as one of five types: complete flake, longitudinal broken flake, transverse broken flake, flake fragment and angular fragment. A complete flake is defined by the presence of a single interior surface, a point of applied force and intact margins (Sullivan and Rozen 1985:759). Presence of a single interior surface, a point of applied force and breaks that interrupt the width dimension define a longitudinal broken flake. A transverse broken flake is defined by presence of a single interior surface, a point of applied force and a break that interrupts the length dimension. A flake fragment is defined by the presence of a single interior surface and no point of applied force (Sullivan and Rozen 1985:759). Angular fragments, also known as debris, are amorphous pieces of broken stone that are not locally derived, have no single interior surface or multiple single interior surfaces and no point of applied force (O'Connor 1990:87).

Using these five types I was able to characterise the degree of post-depositional change between stratigraphic units. Units with a small proportion of complete flakes and high proportions of broken flakes, flake fragments and angular fragments are argued to have been subject to more post-depositional change than units with high proportions of complete flakes and lower proportions of other types.

Artefact manufacture

The second variable relevant to interpreting changes in artefact discard rates is

changes in the system of artefact manufacture. A change in artefact discard may be explained by a change in artefact manufacturing techniques. I examined changes in the system of artefact manufacture by measuring twenty-two attributes on all complete flakes. While lithic analysts remain uncertain about which variables are most valuable in discriminating patterns related to artefact manufacture, robust claims can be made when several variables show the same directional change (Odell 2000:291, Pelcin 1997, Shott *et al.* 2000, Dibble and Pelcin 1995). Complete flakes were measured because they contain the most technological information of the five debitage types and they retain diagnostic characteristics that allow replicable measurements.

When considered together, data on metrics, dorsal flake scars, cortex and platform type can indicate the stage or stages of reduction represented by an artefact assemblage. It is important to measure changes in reduction stages because they can influence the rate of artefact discard. For example, more artefacts may be discarded at the late stages of a reduction system that includes the production of many small flakes during retouching activities compared to early stages where a few larger flakes a discarded to remove core cortex. In analysing data on metrics, dorsal flake scars, cortex and platform type I did not intend to identify specific absolute reduction stages but to make comparisons between relative levels of reduction within and between sites.

Length, width and thickness of complete flakes were recorded in millimetres to one decimal place using Mitutoyo digital vernier callipers (accurate to two decimal places). I measured complete flake length as the line perpendicular from the striking platform through the point of percussion to the most distal point on this line. I measured width as the line between the two margins that is perpendicular to the length dimension at the mid-point of the length dimension. I measured thickness as the line between the dorsal and ventral surfaces that is perpendicular to the width line at the mid-point of the length dimension. Mass of flakes was measured in grams to two decimal places using a Sartorius electronic balance (accurate to two decimal places). The width and thickness dimensions of striking platforms were recorded (along the same planes as the width and thickness dimensions of the artefact) in millimetres to one decimal place using Mitutoyo digital vernier callipers (accurate to two decimal places).

For statistical significance testing metric values were transformed to their base 10 logarithm to ensure they are normally distributed, a requirement for t-tests (Shennan 1997:94-101). I used chi-square tests (Sheskin 2000:359-430) and t-tests (Sheskin 2000:247-87) to calculate the probability that there is no difference between metric and non-metric variables in any two stratigraphic units. To measure the direction of association (positive or negative correlation) in chi-square tests I used the phi coefficient (ϕ) which gives a value approaching –1 for a strong negative correlation and approaching 1 for a strong positive correlation (Sheskin 2000:399). To measure the strength of association between variables investigated in a chi-square test I used Pearson's contingency coefficient (C_{adj}) adjusted to allow comparisons between tables with different numbers of rows and columns (Sheskin 2000:397-8). Pearson's contingency coefficient (C_{adj}) returns a value of 1 for strong associations and 0 for weak associations (Sheskin 2000:397-8). For each test the null hypothesis (H_0) was 'there is no difference between the samples compared'. The null hypothesis was rejected when the probability ($p(H_0)$) calculated by the chi-square or t-test was less than 0.05 (α = 0.05). I calculated the statistics using algorithms in Microsoft Excel.

The metric variables of artefacts recorded here are influenced by the size and raw material qualities of the core, defined here as an artefact with more than one negative flake scar and no bulb of percussion, from which the flake was removed and the amount and location of applied force. Many lithic analysts also use metric variables to determine the stage of artefact production and core reduction, with smaller pieces representing later stages of reduction (Amick *et al.* 1988, Ammerman and Andrefsky 1982, Gilreath 1984, Magne and Pokotylo 1981, Odell 1989, Shott 1994). A high proportion of small pieces may also indicate frequent tool resharpening activities, which may not be related to core reduction. I believe that metric variables alone do not reveal much technological information so I use metric variables in conjunction with other technological variables to provide more convincing interpretations of artefact manufacture.

Dorsal flake scars are the areas on the dorsal surface of a flake where the removal of previous flakes has left negative flake scars. Archaeologists commonly use the number of dorsal flake scars on a flake as an indicator of the stage of production of a stone artefact and an indicator of core reduction (Andrefsky 1998:106, Johnson 1987:193, Magne 1985). Some American researchers suggest that early in the manufacture of a stone artefact there are

few dorsal scars and in the later stages of manufacture there are more dorsal scars (Lyons 1994:33, McDonald 1994:68). Others argue that numbers of dorsal flakes scars are difficult to measure precisely and are more influenced by flake size and flaking technique and raw material than location in reduction sequence (Baumler 1988:262, Shott 1994:80, Maudlin and Amik 1989:73, Odell 1989:178). I recorded the number and orientation of flakes scars on the dorsal surface of each flake. Although dorsal scars alone may be a dubious measure of level for reduction, I believe that convincing descriptions of reduction levels can be made when dorsal scar data is combined with metric, cortex and platform surface data.

Another indicator of level of reduction is the amount of cortex present on the dorsal surface of a flake. Cortex is the surface of a rock that has been exposed to chemical and physical weathering. Archaeologists use the proportion of cortex on cores and flakes as an index of core reduction (Andrefsky 1998:101) and American experimental studies have shown that cortex is a reliable measurement for discerning between earlier and later reduction stages (Odell 1989:185, Maudlin and Amik 1989:70, Magne and Pokotylo 1981). I recorded the proportion of cortex on cores and the dorsal surface of flakes to the nearest ten percent. For complete flakes a value of 100% cortex for a flake indicates that the entire dorsal surface is cortex. It is important to note that much experimental work on stone artefacts has occurred in the United States of America because these experiments seek to replicate and analyse a biface stone artefact technology that is quite different from the artefact manufacturing traditions of the inland Pilbara. Although the analogical relevance of the American experimental evidence to the inland Pilbara is limited by the differences between the two artefact traditions, I use it because it is well documented and there is no ethnographic or experimental evidence directly relevant to inland Pilbara artefact technologies.

The striking platform surface is a further indicator of variation in preferred flaking techniques and is often used as an indicator of reduction (Tomka 1989:147, Morrow 1984:21, Magne and Pokotylo 1981:36). I recorded striking platform surfaces as cortical, flat or faceted. A cortical platform has a platform of the unmodified cortical surface of the artefact. Flakes removed early in the sequence of reduction are characterised by cortical platforms and a high percentage of dorsal cortex (Andrefsky 1998:94, Hiscock 1988:372). A flat platform is a single smooth surface, often a section of a negative flake scar where a flake was previously removed. Facetted platforms have a surface with two or more flake scars. A facetted platform may result from core rotation at an advanced level of reduction or platform preparation (Hiscock 1988:373).

Data on metrics, dorsal flake scars, cortex and platform type were used to indicate the relative stage or stages of reduction represented by each stratigraphic unit. In addition, I wanted to know whether the reduction stage was influenced by raw material economics. I recorded data on raw material type, colour and pattern (banded or non-banded), flake termination, platform type, platform angle and overhang removal.

Raw material economics refers to changes in the supply of raw materials suitable for artefact manufacture. Changes in types of raw material may require changes in artefact manufacture because of differences in mechanical properties, nodule sizes and availability. I recorded raw material type and raw material colour and pattern for each flake. I found it necessary to record colour and pattern because of the high variability within raw material types. I was particularly interested in changes in the numbers of artefacts made from local chert from banded ironstone formation (bif-origin chert, distinctive because of its fine banding) and exotic chert (without bands). I maintained consistency in raw material identification by periodic checks with Jenny Bevan, curator of the E. de C. Clarke Geology Museum, University of Western Australia.

I measured the termination of a flake as an indicator of the amount and location of applied force. A scarce raw material, as well as having smaller metric measurements and more frequently represented by later stages of the reduction system, will probably also have been more carefully manufactured to avoid waste. Flake termination is a measure of 'care' of manufacture as it indicates whether too much, too little or an appropriate amount of force was applied and whether the force was applied in the appropriate location and direction to produce a flake. I recorded four varieties; feather, hinged, stepped and overshot. A feather termination is when the flake gradually shears away from the core to form a smooth and sharp distal end (Cotterell and Kamminga 1987:699). Feather terminations occur when the applied force is sufficient to create a fracture through the core without changing direction (Hiscock 1988:12). A hinge termination can be identified when the proximal end of a flake is

rounded and the ventral surface curves back to the distal surface (Cotterell and Kamminga 1987:700-1). Hinge terminations occur when the applied force is insufficient to form a feather termination and when the applied force is directed away from the core (Cotterell and Kamminga 1987:700-1, Crabtree 1968:451). A stepped termination occurs when the distal end of an artefact snaps or shatters to form an almost 90 degree angle with the ventral surface. A stepped termination occurs when the applied force is insufficient to complete a feather termination or a significant flaw in the rock interrupts the force (Cotterell and Kamminga 1987:700). An overshot termination occurs when the applied force turns or rolls inwards away from the flake and results in a large portion of the flake attached at the distal end (Andrefsky 1998:86). Overshot terminations result from force applied away from the edge of the core, or the applied force exceeding that required for a feather termination (Hiscock 1988:12, Crabtree 1968:466).

The Sullivan-Rozen typology provides no way of discerning between a proximal broken flake and a complete flake with stepped termination. I define a complete flake with stepped termination as a complete flake with a combination of stepped and hinge or feather termination, where the stepped section is more than half of the width of the termination. A proximal broken flake has a stepped termination that runs the entire width of the termination.

Another indicator of amount and location of applied force is platform type. Striking platform type is an expression of the relationship between the point of applied force to the rest of the platform area (Hiscock and Hall 1988:86). Analysis of platform type provides an indication of the preferred flaking techniques of flake manufacturers. I recorded platform type as wide, focalised or gull-winged. A wide platform is defined as a surface where the surface area of the platform is more than twice the area of the point of applied force. A focalised platform is defined as a platform that is less than twice the area of the point of applied force. A gull-winged platform is usually thin and wide with a plan view similar to a flying gull face-on. Focalised and gull-winged platforms indicate that the force applied was not excessive and the blow was placed close to the edge. Focalised platforms often result from overhang removal or the application of force to a prominent point on the platform (Hiscock 1988:372). Gull-winged platforms result from the placement of a blow immediately behind the point of applied force of a previously removed flake (Hiscock 1988:372).

I did not measure platform angle. It is a problematic measurement because the dorsal surfaces of flakes are rarely flat and the results are not reliable. Not only do different people consistently record different values for the same artefact but the same person consistently records different values for the same artefact when measured multiple times (Andrefsky 1998:91).

Overhang removal data indicates availability of raw material. Overhang removal is present when there are a number of small negative flake scars at the proximal end of the dorsal surface (Hiscock 1988:367). The small scars are usually interpreted as attempts by the stone worker to make the platform angle close to 90 degrees to prevent platform shatter and increase the probability of producing a complete flake (Hiscock 1988:367, Holdaway and Stern in press:67). When raw material is scarce a higher degree of overhang removal is expected as knappers try to maximise the use of the available material.

Change in the function of the site

A change in the function of a site may result in an increased artefact discard without any increase in the intensity of occupation. I aimed to measure differences in technological organization between stratigraphic units as an index of mobility and duration of visits to see if changes in site use could explain changes in artefact discard rates. Shott's (1986) analysis of mobility and assemblage diversity of 14 ethnographic groups indicates that there is an inverse relationship between assemblage diversity and the number of residential moves a group makes per year. I did not measure assemblage diversity because of the difficulty in distinguishing types in inland Pilbara rockshelter assemblages (Brown 1987) and because some Australian artefact types, such as triangular blades, backed artefacts and grinding stones, may not be associated with mobility levels but with social changes (cf. chapter two, Allen 1996, Bowdler and O'Connor 1991).

Shott (1986, 1996) observed that highly mobile ethnographic groups with low assemblage diversity tend to use stone artefacts that are multifunctional and highly curated. Based on ethnoarchaeological evidence Shott (1989, 1996) proposed that the level of artefact curation, defined as 'degree of use' or the difference between the potential utility the tool starts with versus the potential

left at discard, increases with mobility. Parry and Kelly (1987) similarly use ethnographic accounts from New Guinea and Brazil of flaked artefact manufacture and use to argue that expedient technologies consisting of unstandardised core reduction and a low frequency of resharpening may be linked to low levels of residential mobility. Parry and Kelly (1987:303) argue that less mobile groups employ an unstandardised core reduction strategy because they need to minimise time and effort but not raw materials because raw materials can be stockpiled. Conversely, Parry and Kelly (1987:303) argue that for highly mobile groups it is advantageous to invest time and effort into producing formalised tools and frequent resharpening because these tools are more portable and provide more cutting edge per unit of mass.

Kuhn's (1991) interpretation of curation as an indicator of duration of site occupation may be more appropriate than the generalised descriptions of settlement mobility of Parry and Kelly (1987) and Shott (1986, 1996) for understanding stone artefacts assemblages produced by arid zone Australian Aboriginal people. In his analysis of two Mousterian sites in west-central Italy, Kuhn (1991) follows the arguments of Parry and Kelly (1987) that, in general, more sedentary populations will use an expedient technology and more mobile populations will use a formal technology with a high frequency of retouch. Unlike Parry and Kelly (1987) and Shott (1986, 1996), Kuhn (1991) discerns between duration of occupation, which can be seasonal or specific to site function or location, and sedentism.

It should be noted that assemblage qualities such as curation, frequency of resharpening and standardisation of cores are also influenced by raw material availability, the use of non-lithic raw materials, efficiency of design, use and resharpening, the social functions of artefacts and site function (Shott 1996:267-8, Parry and Kelly 1987, Bamforth 1986, 1991). An ethnoarchaeological study by Gould *et al.* (1971) of artefact assemblages produced by Australian Western Desert Aboriginal people provides examples relevant to the inland Pilbara of some factors that can interfere with the mobility-curation relationship. Gould *et al.* (1971:155) describe a range of artefacts that are exclusively used by men and are kept hidden when not in use because they are not allowed to be seen by women, children and uninitiated males. Examples of these tools include a small engraving tool used for making incised decorations on sacred boards and decorated spearthrowers and long flakes used to circumcise males (Gould *et al.*

1971:155). The social function of these artefacts suggests that their level of curation has no relationship to frequency of residential moves. Gould *et al.* (1971:162) also describe stockpiling of raw materials and trade, procurement strategies assumed by Parry and Kelly (1987) to be typical of less mobile groups.

A particularly interesting detail noted by Gould *et al.* (1971) is the combination of curated and expedient technology used by Western Desert Aboriginal people. Gould *et al.* (1971) describe two types of adzes (*tula* and *burren*) used for woodworking that are standardised and frequently retouched. Gould *et al.* (1971:161, Gould 1980:124-5) also observe that lithic procurement by Western Desert Aboriginal people can result in a ratio of flake to waste pieces of 1:200-600, generating 'the tremendous quantities of unused stone flakes which one characteristically finds on the surface of Aboriginal quarries'. Gould *et al.* (1971:163) observe that 'the chipping of stone tools is regarded by these people [Nyanunyatjara, Ngatatjara and Ngatjara language speakers] as an art of little importance', and they describe an Aboriginal man who picked up a used artefact and recycled it by hafting it to his spearthower and several instances of Aboriginal people who 'simply seize a stone, use it for an immediate purpose, and discard it'. The significance of the ethnoarchaeological observations of Gould *et al.* (1971, Gould 1980) is that Australian Aboriginal people in arid environments, considered by Parry and Kelly (1987:301) to be highly mobile, use a combination of expedient and curated stone artefact technologies that are not always related to measures of mobility such as frequency of residential moves. This implies that the mobility-curation relationship proposed by Parry and Kelly (1987) and Shott (1986, 1996) may not be applicable to artefact assemblages produced by Aboriginal people inhabiting the inland Pilbara.

I measured curation as the proportion of cores and artefacts with secondary working in the assemblage. The significance of changes in curation for residential mobility and duration of occupation is difficult to discern in the four inland Pilbara sites examined here because raw materials are abundant throughout the Hamersley Plateau and the long periods represented by small artefact assemblages. I interpret changes in curation as indicative of changes in mobility and duration of occupation only when changes in curation are coincident with changes in other relevant variables such as raw materials, artefact size, platform variables (type, surface and overhang removal) and

magnetic susceptibility (for Marillana A and Cleft Rock Shelter). For artefacts with secondary working I recorded the length and shape of working, the angle of the working to the ventral surface and the type of working.

Increase in site use

Where there is an increase in rate of artefact discard that is not accompanied by technological or functional change, not explainable in terms of post-depositional change and coincident with increases in other cultural and non-cultural variables, I interpret this change as an increase in the intensity of site use. With evidence from other sites it may be possible to suggest if the increase in occupation intensity results from environmental stress, demographic changes or is an independent local response particular to one rockshelter.

CONCLUSION

In this chapter I have described and explained the methods used in the analysis of archaeological evidence in this project. In the following chapters I show how the methods presented here allowed me to identify changes in cultural systems and population dynamics at four inland Pilbara rockshelters.

4. Results and analysis: Marillana A

Introduction

Chapters four to seven describe the results of my analysis of sediments, organic materials and stone artefacts from four rockshelters, Marillana A, Marillana B, Cleft Rock Shelter and Milly's Cave, excavated in the inland Pilbara (figure 4.1). The rockshelters were excavated by Lynda Strawbridge in 1989-1993 during heritage management work for the Yandicoogina iron ore development of BHP Utah Minerals International. Strawbridge's (pers. comm. 2001) aims in selecting the rockshelters for excavation were to investigate Aboriginal occupation on a proposed railway route, so she choose shelters situated near drainage lines big with enough floor space and head room to seat five or six people.

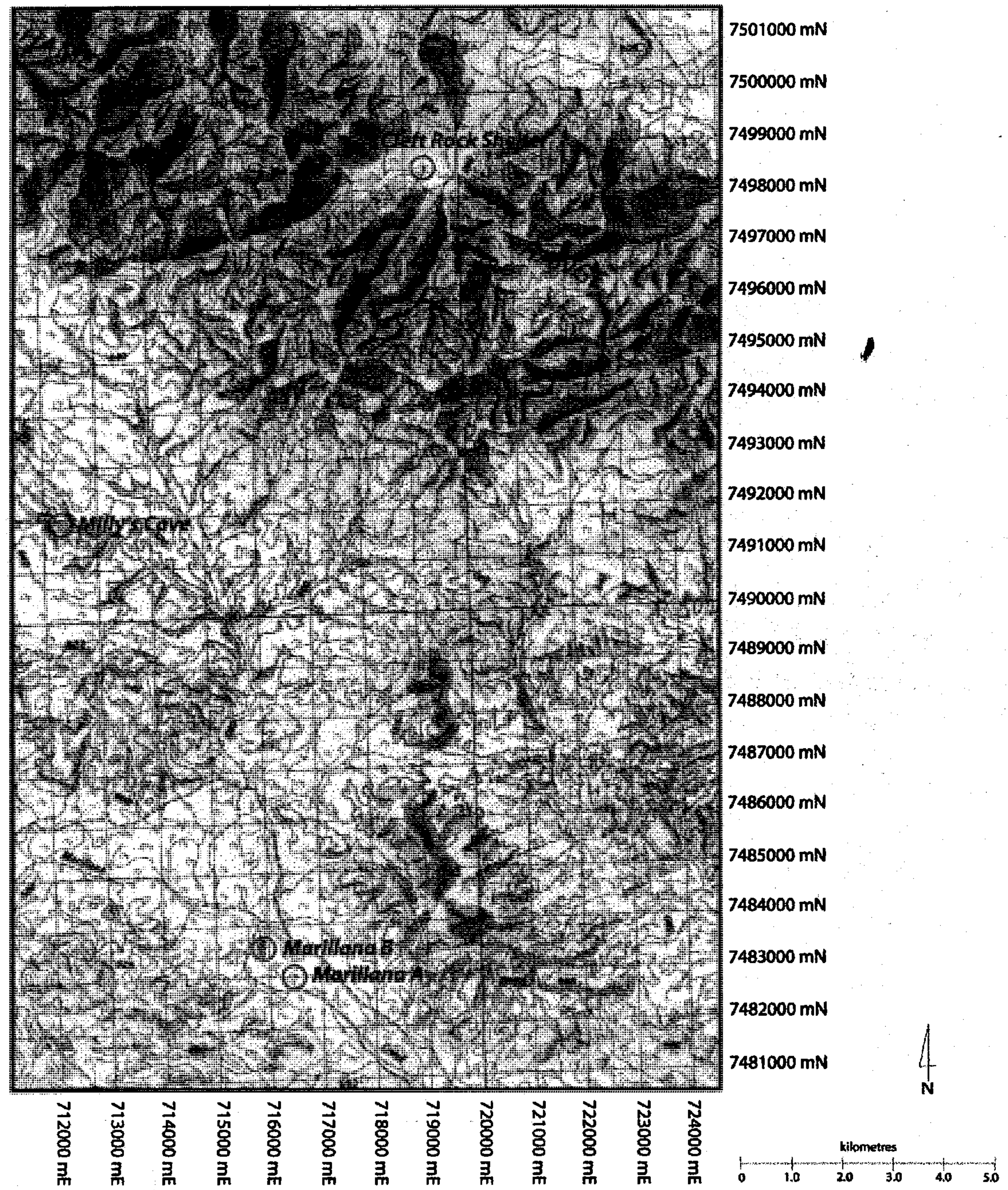
In chapters four to seven I present new evidence from the four rockshelters to answer the questions of how people in the inland Pilbara responded to the extreme environmental changes of the LGM and what the cultural, economic and demographic implications were of the appearance of new stone artefact types and increases in the intensity of site use and the numbers of sites occupied during the middle and late Holocene. In this chapter I discuss the results of my analysis of Marillana A. I discuss this site first because it has the longest and most complete record of sediments and organic materials of the four sites, providing an impression of conditions at the other three sites where sedimentary evidence was not available for analysis. In chapter five I discuss Marillana B, located near to Marillana A, but with quite a different pattern of occupation. In chapter six I discuss Cleft Rock Shelter, located in the escarpment away from Marillana A and B, which shares some similarities in its history of occupation with Marillana A. In chapter seven I discuss Milly's Cave, geographically midway between Cleft Rock Shelter and the Marillana shelters, but is distinctive because it is the only site of the four with a history of occupation extending to before the LGM.

It should be noted the material excavated by Strawbridge has been in storage in a number of different locations on the Crawley campus of the University of Western Australia. Changes in the location of the material have resulted in the sampling gaps in the sedimentary record and possibly in organic material and charcoal because material is lost or disposed of during the moving process. I have no way of discerning between excavation units that had no charcoal or organic material in them or bags that have gone missing since excavation, so it is not possible to quantify the exact extent of these post-recovery losses.

Although summaries of the excavations at Marillana A, Marillana B and Cleft Rock Shelter have been provided by Strawbridge (1988, 1992) in unpublished consultant reports produced for BHP Utah Minerals International, I have not relied heavily on details from these reports in these chapters. The information presented in this chapter on site location, site description, some of the radiocarbon dates, stratigraphy and excavation methods for comes directly from the more detailed accounts in Strawbridge's unpublished field notebooks. Unless otherwise stated the descriptions of site locations, excavation techniques and stratigraphic data (section drawings, pH and colour determinations) provided here were taken from the field notes or personal communication with Lynda Strawbridge.

The data collected and analysed for the four rockshelters is available on the compact disk attached to the back cover. If the disk is not in the back cover the data may be obtained by contacting the author or the University of Western Australia Centre for Archaeology. Appendix 1 describes the format of the data and explains the abbreviations used in the spreadsheets.

Figure 4.1 Topographic map showing the location of the four sites discussed in chapters four to seven. Contour intervals are 20 m, elevations in metres above sea level. This map is an excerpt from Weeli Wolli, Western Australia, Sheet 2752 (Edition 1) 1975, National Topographic Map Series.



Marillana A

Marillana A (also known as Waterfall Rockshelter) is a long south-facing rock overhang in Marra Mamba ironstone formation at the top of a short steep-sided gully that runs off Marillana Creek (figure 4.1). Strawbridge (1992:40) notes that these waterways only flow intermittently, but that large volumes of water drain into this gully creating a small waterfall (adjacent to the rockshelter) and pools during rainy periods. The shelter is 22.5 m wide and 6.5 m high at the drip line and 5.5 m deep (figures 4.2-4.4). Large boulders of roof-fall occur across the front of the shelter, 2.5 m beyond the drip line. These boulders have prevented sediments from moving out of the rockshelter, resulting in a large level surface suitable for human occupation (Strawbridge 1992:40). Grinding pieces and other stone artefacts occur over much of the surface (Strawbridge 1992:40). The surface material was not available for me to analyse.

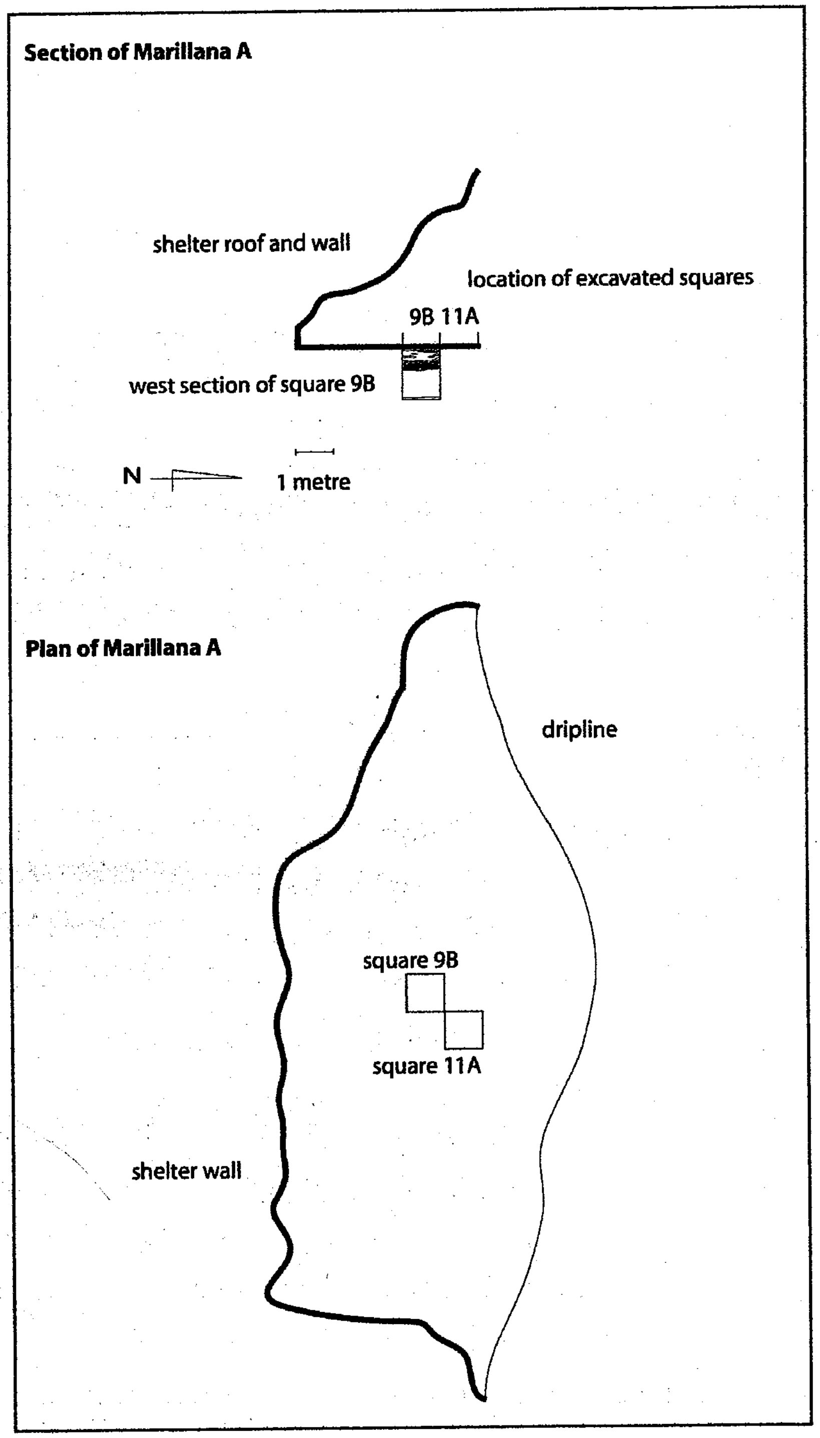
EXCAVATION

The shelter was excavated in 1991 and 1993 by Lynda Strawbridge and students from the University of Western Australia. Local Aboriginal people visited the site while the excavation was in progress. In 1991 a one by one metre square (labelled 11B) was excavated in 16 spits of about six centimetres each to a depth of 99 cm (figure 4.5). The square was located just behind the drip line at a point where the depth of the shelter was greatest (Strawbridge 1992:40). In 1993 a second one by one metre square (labelled 9B) was excavated in 53 spits (excavation units) of about three centimetres each to a depth of 147 cm. Two adze slugs were found on the surface.

Figure 4.2 Photo at Marillana A from Strawbridge (1992:fig 7). Original caption: 'View from rockshelter across ephemeral water course towards Marillana Creek'.

Figure 4.3 Photo at Marillana A from Strawbridge (1992:fig 8). Original caption: 'View of excavations in progress'.

Figure 4.4 Section and plan of Marillana A rockshelter. Redrawn from Strawbridge's field drawings and measurements.



THE TIMING OF OCCUPATION

To identify the time represented by Marillana A and the timing of changes in site formation processes I used radiocarbon dates, Strawbridge's field descriptions and my analysis of sediment particle size and colour from square 9A to group similar excavation units into stratigraphic units. Figure 4.5 shows Strawbridge's section drawing of the north section of square 9B made in the field. Figure 4.6 shows the results of my analysis of sediments from all samples available. From Strawbridge's field section drawings and my sediment analysis I identified and radiocarbon dated four stratigraphic units at square 9A.

Stratigraphic units one and two were identified from Strawbridge's section drawing and field notes and my analysis of sediment colour. Strawbridge's section drawing and field descriptions identifies stratigraphic unit one as a 12 cm deep brown-grey (5YR3/3 oven dried in the laboratory) loose ashy surface deposit overlaying stratigraphic unit two, a more compact light brown (10YR3/2 oven dried in the laboratory) layer with ash lenses to a depth of 40 cm. Strawbridge (pers. comm. 2001) recognised that the difference in colour and texture may indicate a change in site use or site formation and obtained a date of 3630±70 BP from about 15 cm below the surface (excavation unit two in square 11A) at the interface of the two stratigraphic units. In square 9A the first stratigraphic unit includes excavation units one to four and the second stratigraphic unit include excavation units five to 20.

My analysis of sediment colour (figure 4.5) confirms Strawbridge's observations, but I did not identify any differences in sediment particle size proportions in the two stratigraphic units (figures 4.6 and 4.7). The absence of differences in particle size distribution between the two stratigraphic units is probably because only one sample (excavation unit three) was available for stratigraphic unit one and this sample may not be representative of stratigraphic unit one.

Figure 4.5 North section of excavated square 9B at Marillana A. Redrawn from Strawbridge's field drawings. Dates in brackets indicate that they were obtained on charcoal from square 11A.

SU= stratigraphic unit
lab= analysis undertaken under laboratory conditions during 2001-2

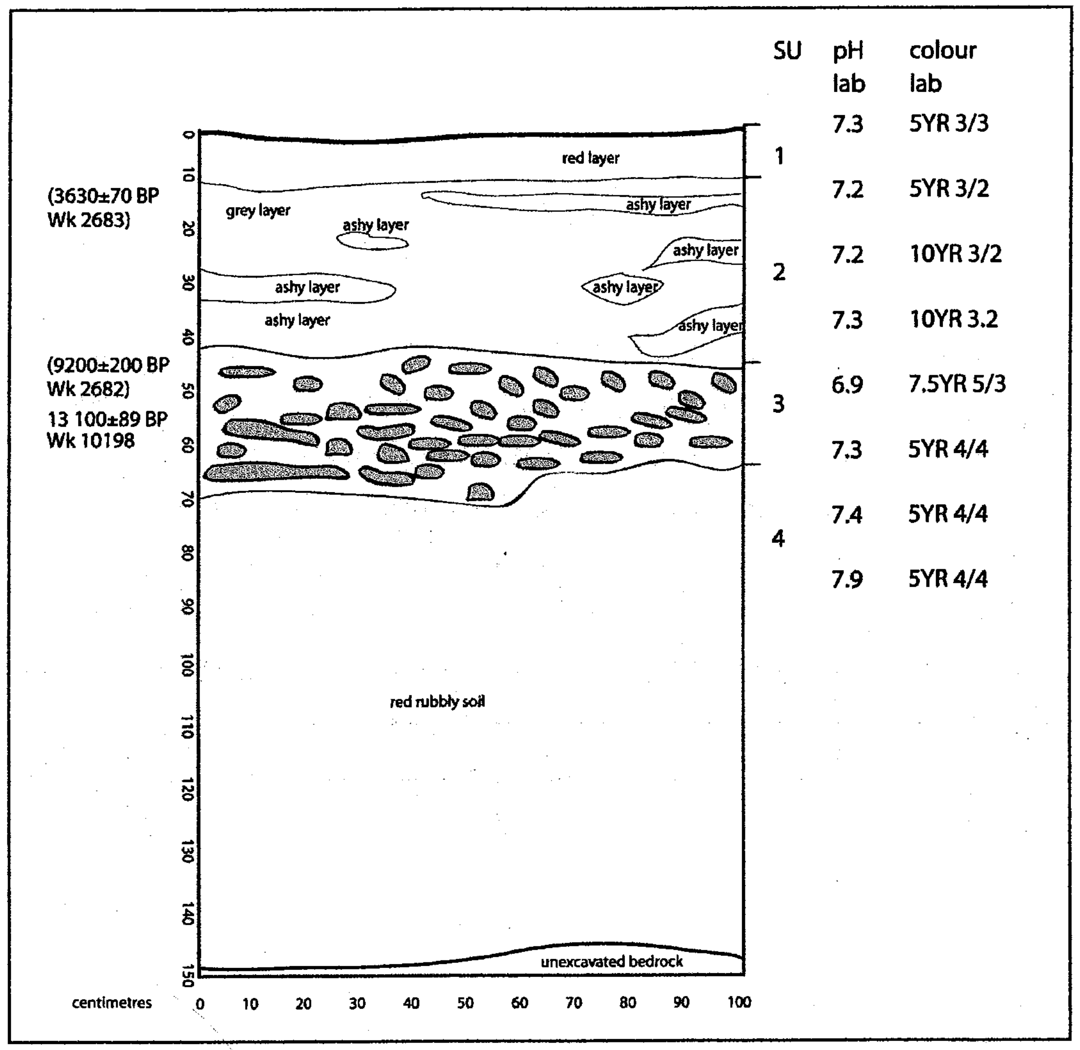


Figure 4.6 Particle size distribution at Marillana A square 9B. Particle size fractions expressed as phi.

SU = stratigraphic unit

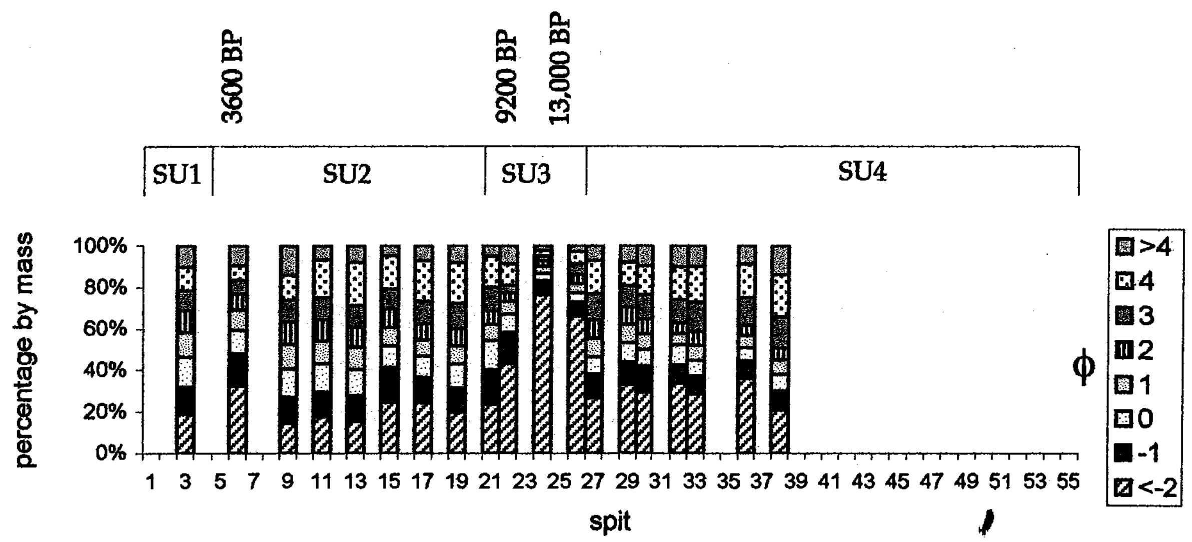


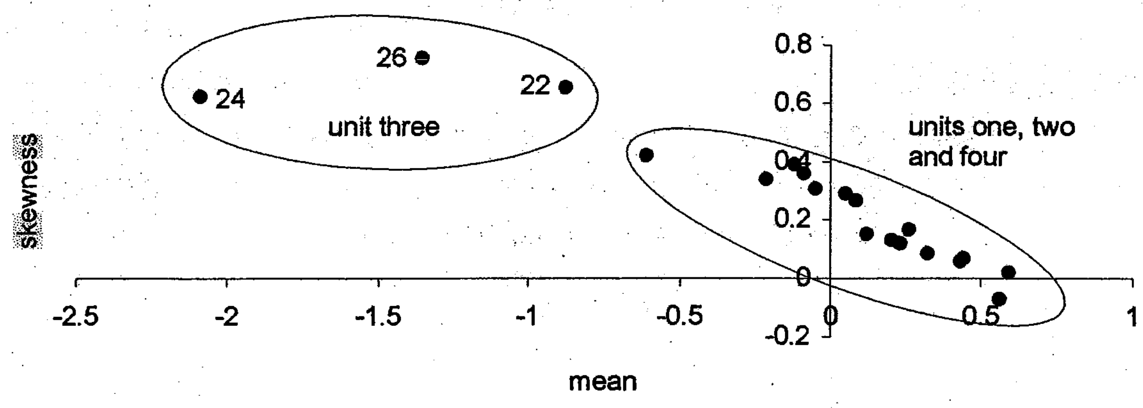
Table 4.1 Particle size statistics for Marillana A square 9B

SU = stratigraphic unit
EU = excavation unit

SU	EU	mean	sorting (s)	skewness (*Sk*)	kurtosis (*K*)
1	3	0.120	2.198	0.150	0.724
2	6	-0.612	2.058	0.421	0.802
2	9	0.322	2.179	0.084	0.736
2	11	0.444	2.315	0.067	0.654
2	13	0.594	2.317	0.020	0.632
2	15	0.084	2.340	0.268	0.631
2	17	0.262	2.399	0.166	0.573
2	19	0.433	2.362	0.058	0.603
3	21	0.050	2.315	0.290	0.628
3	22	-0.875	2.112	0.654	0.971
3	24	-2.091	1.172	0.624	3.179
4	26	-1.355	1.855	0.757	1.503
4	27	0.203	2.366	0.129	0.588
4	29	-0.217	2.290	0.342	0.635
4	30	-0.051	2.355	0.310	0.594
4	32	-0.090	2.409	0.360	0.570
4	33	0.232	2.413	0.119	0.557
4	36	-0.122	2.420	0.390	0.555
4	38	0.563	2.412	-0.072	0.555

I identified stratigraphic unit three from Strawbridge's records and my analysis of colour and particle size distribution. Strawbridge's section drawing describes a layer about 40 cm to 65 cm below the surface (excavation units 21-25) as 'roof fall'. The colour of the three sediment samples from this depth range (excavation units 22, 24 and 26) is lighter than samples from above and below, suggesting different formation conditions during this period (figure 4.5). Analysis of particle size distribution in these three sediment samples shows a higher proportion of large clasts in these sediments compared to others (figure 4.6, table 4.1). Figure 4.7 shows that the skewness and mean values of the particle size distributions from excavation units 22, 24 and 26 are substantially different from other excavation units. Like the difference in colour, the particle size evidence suggests that these three excavation units formed under different conditions to the other excavation units.

Figure 4.7 Particle size mean vs. skewness at Marillana A square 9B



The sediment data for stratigraphic unit three suggest a period when net sedimentation rates fall to zero. Predicted outcomes of zero net sedimentation rates include higher sorting, coarser grain sizes, and higher mass/unit volume ratios in condensed sequences where particle size ranges of available sediment are restricted (O'Connor *et al.* 1999:64). The high skewness values for sediments in excavation units 22, 24 and 26 indicate that these excavation units are more highly sorted than other excavation units (table 4.1, figure 4.6). Coarser grain sizes in these three excavation units are reflected in the high negative mean values (table. 4.1, figure 4.6).

Two radiocarbon dates define the period represented by stratigraphic unit three. From square 11B there is a date of 9200±200 BP from 46-51 cm below the surface (excavation unit eight) (Strawbridge 1992:41). From square 9B there is a date of 13,167±89 BP (Wk 10198) from a depth of 48-51 cm below the surface (excavation unit 22). The 9200±200 BP date and the 13,167±89 BP date come from overlapping depths below surface, although there is a horizontal distance of about one metre between them (figure 4.4). The vertical closeness of these two dates suggests that one or both lack precision or accuracy, or that they indicate a 3900 year period of reduced sedimentation or that sedimentation was uneven over the rockshelter floor. While further dates are necessary to determine the precision and accuracy of the two dates, the particle size data from square 9A described above are consistent with a 3900 year period of reduced sedimentation at the depth of the two dates (45-60 cm).

Stratigraphic unit four was identified from Strawbridge's section drawing and my analysis of particle size data. Strawbridge records a homogenous deposit of 'red rubbly soil' from the base of the roof fall layer to bedrock (65-147 cm, excavation units 27-55). In stratigraphic unit four particle size distributions are similar to units two and three (table 4.1, figure 4.6). Compared to units one and two, mean sizes in unit four are lower and standard deviations are higher (figure 4.7). The lower means and higher standard deviations in unit four, compared to units one and two, suggest that the unit four sediments were subject to increased erosion that removed sediments in size classes 0-3ϕ. I was unable to date the base of stratigraphic unit four because no charcoal was available.

The conditions of increased erosion suggested for stratigraphic unit four may have resulted from slower sedimentation rates or different climatic conditions. In the absence of a date from the base of stratigraphic unit four and palaeoenvironmental data for the inland Pilbara, it is not possible to determine the cause of the increased erosion of sediments. Interpretations of archaeological sites elsewhere (discussed in chapter three) suggest that stratigraphic layers with relatively little or no evidence of human occupation have slower sedimentation rates than stratigraphic layers with high densities of evidence of human occupation. If Marillana A is analogous to these sites then the increased erosion of sediments in stratigraphic unit four may reflect a lower intensity of human occupation than units one and two.

SOURCE OF SEDIMENTS

The trend of bimodality of large grain sizes (<-2ϕ) and very small grain sizes (>3ϕ) in the sediments throughout units one, two and four (figure 4.6) probably results from the breakdown of the rockshelter walls and the deposition of windblown sediments. The rockshelter walls are Marra Mamba ironstone, a formation of alternating thin horizontal bands of chert and ironstone (Trednall 1975). Weathering causes iron oxides to form and as iron oxides are less dense than ironstone, and the chert does not oxidize at the same rate, pieces of rock fracture away from the roof and walls of the shelter, contributing to the rockshelter deposit.

Heavy water erosion has made the soils near Marillana A stony, skeletal loams (Williams and Calaby 1985:282-8, Department of Conservation and Land Management 1999:10) with very low proportions of mobile sediments. In addition, the rockshelter is situated away from the water flow that transports soil particles in the open. Analysis of surface soils from Hamersley Station, 80km north-east of Marillana A, shows that 60% of surface soil mass is >3ϕ (Bentley *et al.* 1999:2235), indicating that the high proportion of very small grain sizes observed in the rockshelter deposits probably results from local surface soils carried by the wind as well as weathering of the rockshelter.

CHANGES IN THE INTENSITY AND TYPE OF OCCUPATION

Organic material and soluble salt concentration

I analysed rates of deposition of sedimentary organic material, including charcoal and faunal remains, soil organic material and soluble salt concentration as possible measures of changes in the intensity of human occupation at Marillana A. I did not analyse soil organic material or soluble salts from square 11B because I was unable to locate sediment samples for square 11B. I analysed material from both squares (where available) to see if there is evidence of local changes in the use of parts of the site or changes in the use of the entire site. Sedimentary organic material (organic material retrieved by Strawbridge from the sieves) is most highly concentrated in stratigraphic unit one and declines to zero in unit two of square 9A (figures 4.8-4.9). The absence of sedimentary organic matter from the lower units may be explained by decay and poor preservation due to slower rates of sedimentation during their formation. In 9A the organic material consists of 18.61 g of plant matter and in 11B organic material consists of 34.85 g of plant matter, 14.66 g of *Macropus* sp. scats and 0.48 g of insect exoskeletons. The presence of *Macropus* sp. scats suggests that the most recent use of the rockshelter was as a *Macropus* sp. sleeping or resting place and that the organic material is probably more related to animal activity and soil formation processes that human occupation.

Figure 4.8 Sedimentary organic material distribution at Marillana A square 9A

SU = stratigraphic unit

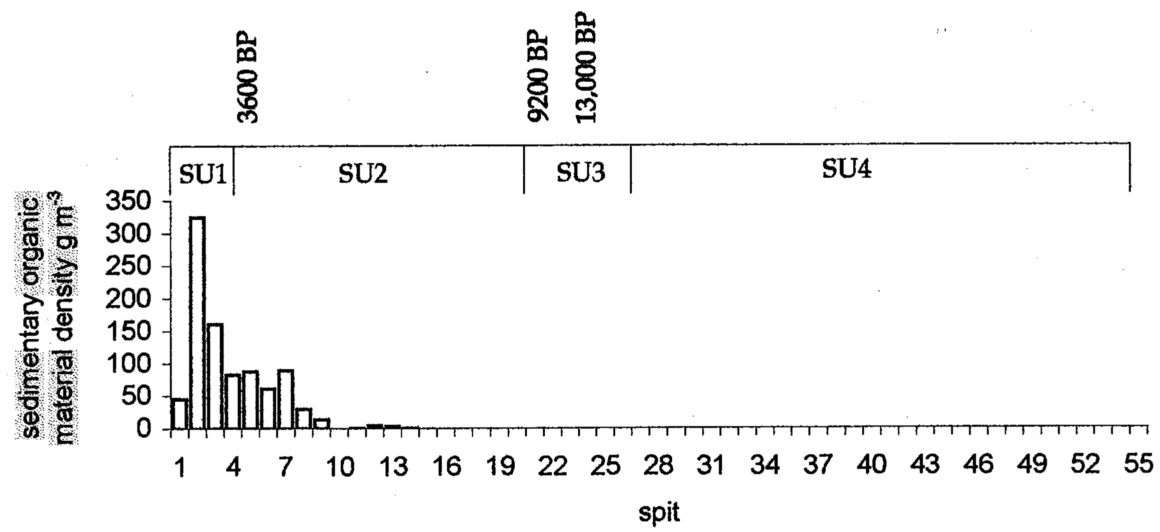


Figure 4.9 Sedimentary organic material distribution at Marillana A square 11B

SU = stratigraphic unit

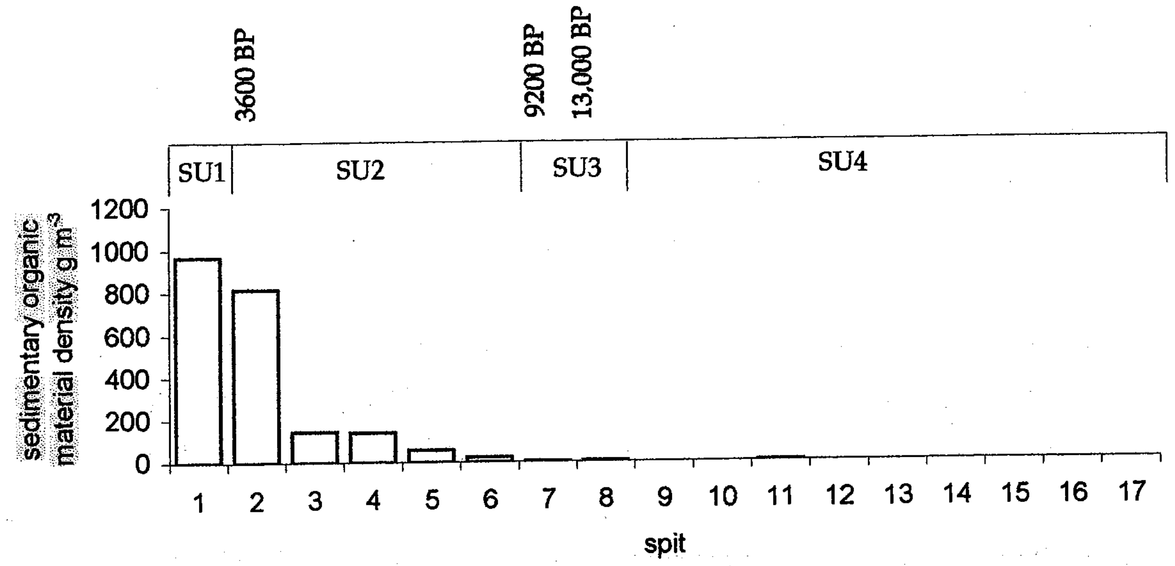
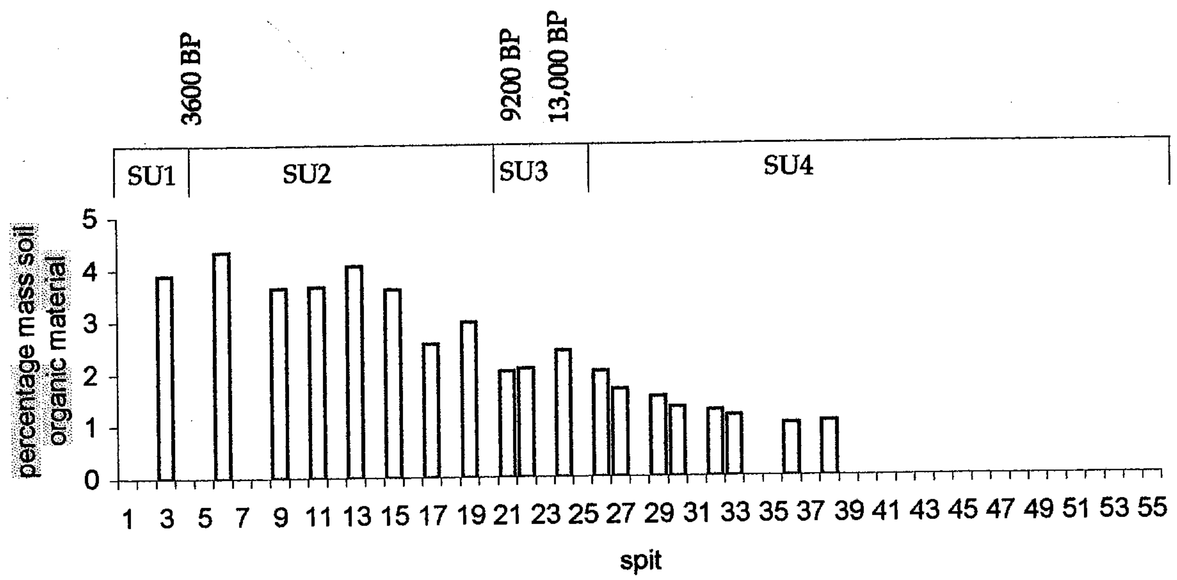


Figure 4.10 shows the percentage of soil organic material in each spit at square 9B. No sediments from square 11A were available for me to analyse. The concentration of soil organic material is similar to the distribution of sedimentary organic material, highest in units one and two, and gradually declining with depth. The similar patterns in the distribution of sedimentary and soil organic material suggests that decay and poor preservation may have influenced the distribution of organic material more than human occupation patterns.

Figure 4.10 Soil organic material distribution at Marillana A square 9B

SU = stratigraphic unit



Figures 4.11-4.12 shows the distribution of charcoal in the two squares excavated at Marillana A. Like other organic matter, the majority of charcoal mass occurs in the upper excavation units, which is probably a result of increased occupation intensity in these excavation units and poor preservation of charcoal in older excavation units because of decay and slow rates of sedimentation. On the other hand, the difference between the charcoal and soil organic material distributions suggests that charcoal distribution may not be solely determined by preservation conditions and that it may reflect cultural activities including hearth fires for warmth and cooking. The distinct ashy lenses documented by Strawbridge in her field drawings (figure 4.5) suggest that some of the charcoal recovered from stratigraphic units one and two of square 9B resulted from hearth fires.

Faunal remains, like other organic materials, are most abundant in the upper units but because bones are more durable than plant matter they also have survived at a greater depth at Marillana A. The number of individual specimens (NISP) of faunal remains from square 9B is 33 with a total mass of 0.77 g (figures 4.13-4.14). Square 11B has a similarly small amount of faunal remains with 58 specimens making a total mass of 3.66 g. The mean mass of total bone in 9B is 0.02 g with a range of 0.07 g to 0.01 g, and the mean mass of total bone in 11A is 0.06 g with a range of 1.5 g to 0.01 g. The small size of the specimens made identification difficult but five specimens in 9B and 10 in 11A are identified as molar fragments of *Macropus* sp. In 11A the mass/NISP ratio decreases with depth below surface suggesting that older specimens are more fragmented than younger specimens. This pattern probably results from the slow rate of sediment accumulation that exposes the bone to physical and chemical weathering for long periods.

Figure 4.11 Charcoal density at Marillana A square 9B

SU = stratigraphic unit

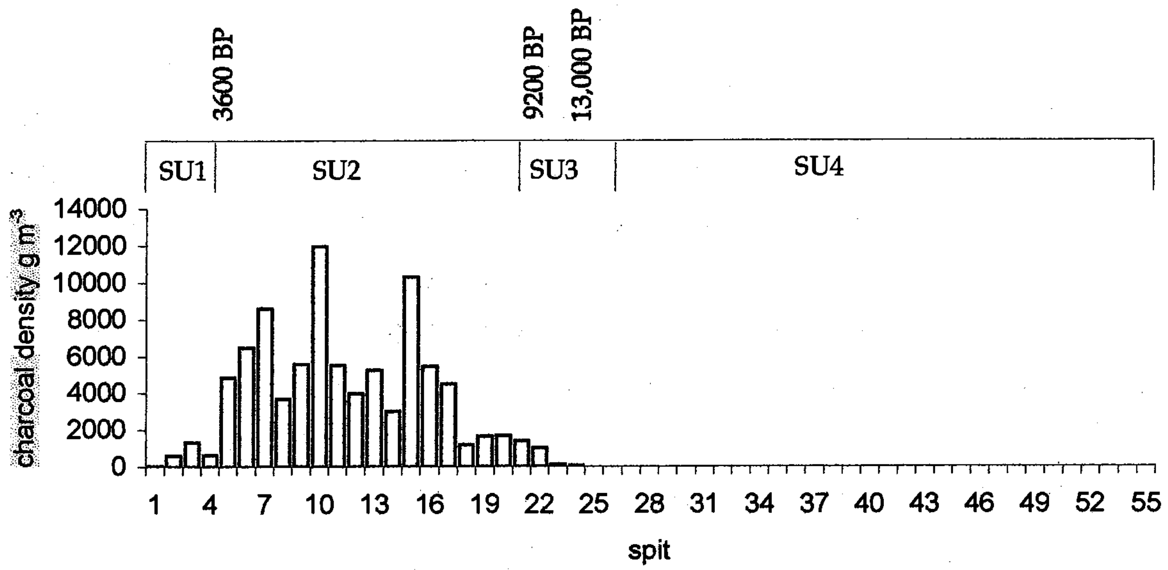


Figure 4.12 Charcoal density at Marillana A square 11A

SU = stratigraphic unit

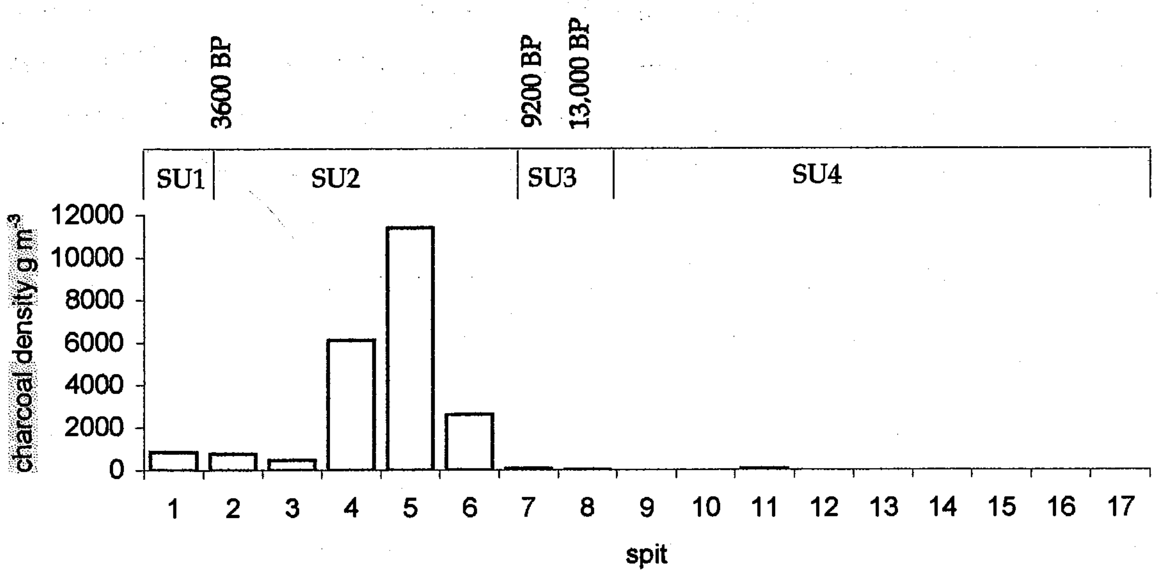


Figure 4.13 Faunal material density and NISP at Marillana A square 9B

SU = stratigraphic unit

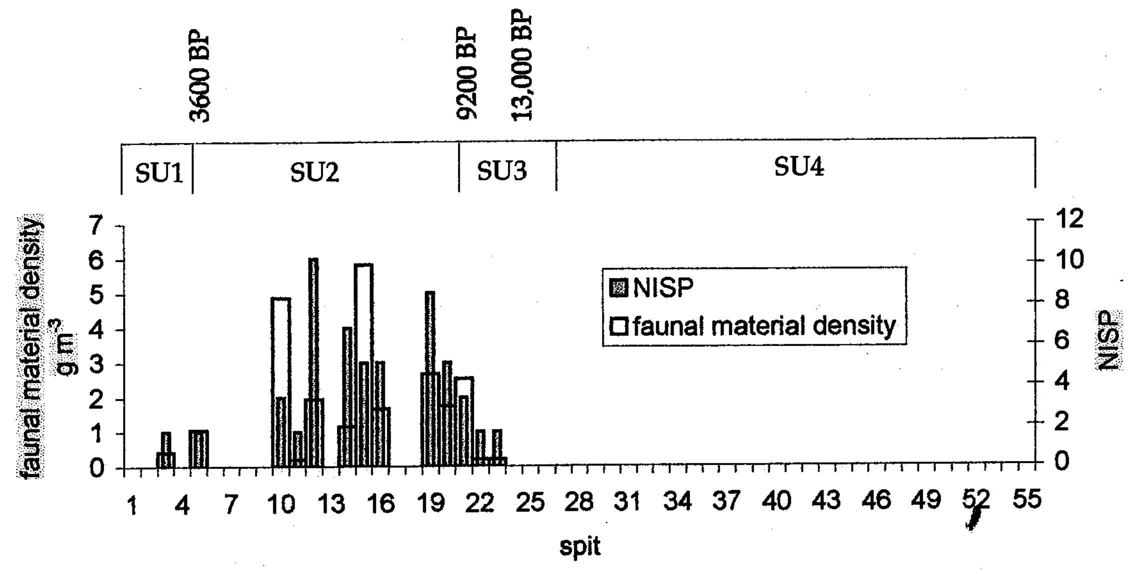
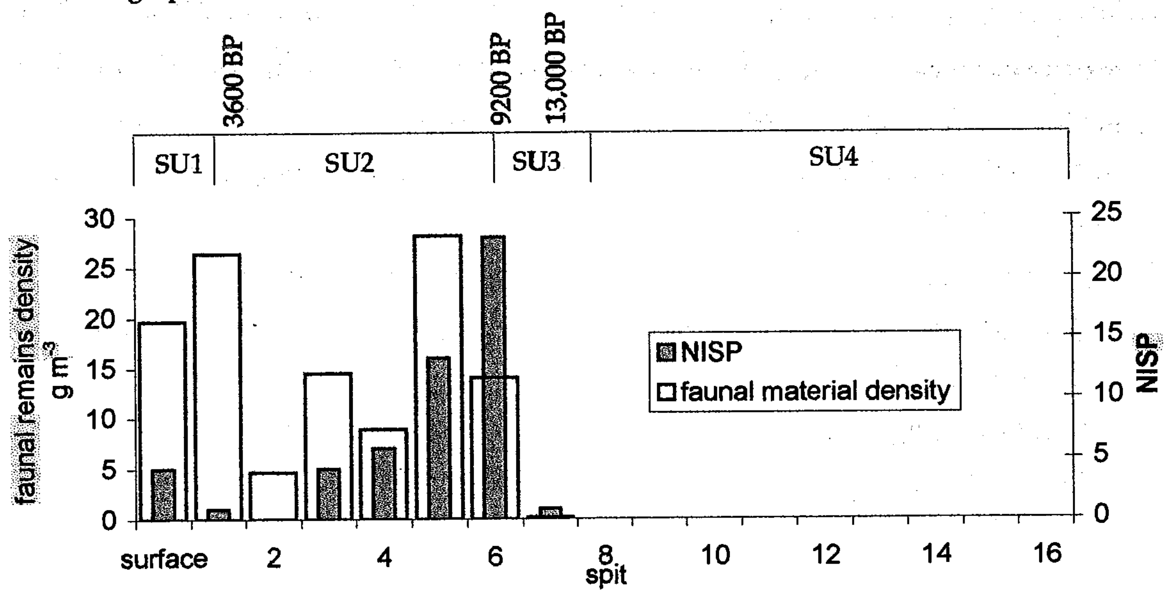


Figure 4.14 Faunal material density and NISP at Marillana A square 11A

SU = stratigraphic unit



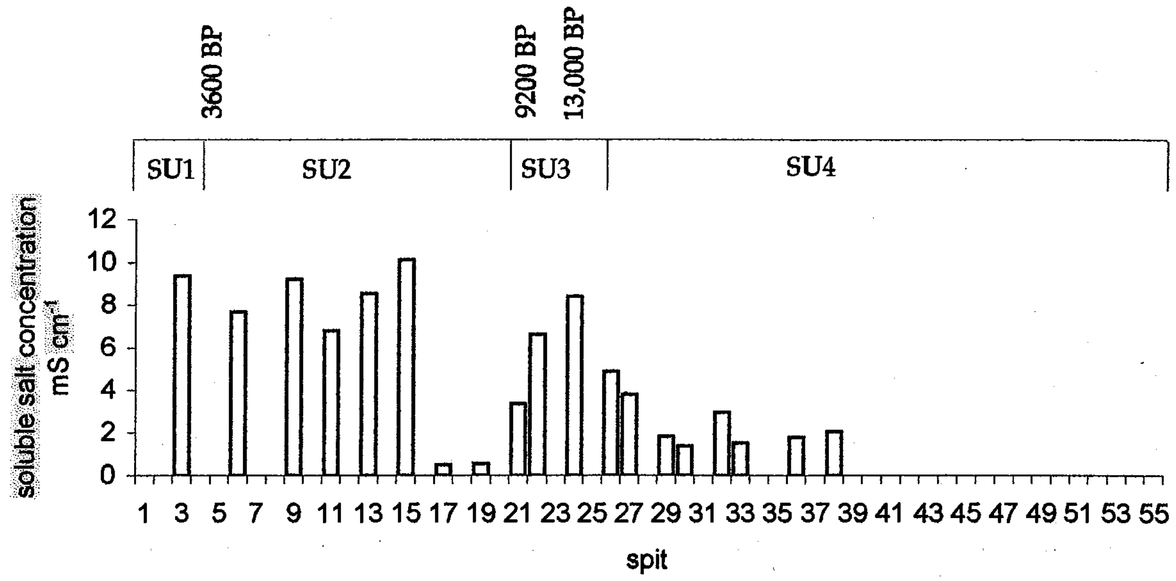
Fragmentation of Macropod teeth has been argued by O'Connor *et al.* (1998) and Gould (1996) to result from people pulverising teeth to make them edible, but at Marillana A I believe that mammalian carnivores were the primary agents of accumulation. Using evidence from Puntutjarpa, Intitjikula and Serpent's Glen rockshelters, O'Connor *et al.* (1998) and Gould (1996) have argued that assemblages of fragmented Macropod teeth were created by people suffering protein stress pulverising bone to extract marrow. In response, Walshe (2000) reviewed the faunal data from Puntutjarpa, Intitjikula and Serpent's Glen and found that similar patterns of bone fragments at other sites in Australia result from the activity of dingoes, Tasmanian devils, quolls and other predators. Walshe (2000) also notes that ethnographic accounts of Aboriginal marrow extraction describe the production of a few large fragments of long bones rather than many small bone pieces. In reply to Walshe, Gould *et al.* (2002) argue that Tasmanian devils were not present in the Western Desert and therefore could not have contributed to fragmentation of faunal material. They also argue that while the dingo was present, other studies (e.g. Pocock 1988) suggest that the dingo has little impact on the degree of fragmentation of faunal assemblages.

The absence of any signs of burning, butchery or other patterns of human modification on faunal material at Marillana A suggest that bone was accumulated by non-human carnivores or a result of animals dying in the shelter and exploited by scavengers. It should be noted that the degree of fragmentation makes identifying signs of human modification difficult, and I cannot exclude the possibility of human modification of the assemblage. Teeth are the most durable remains of all fauna and *Macropus* sp. have probably been nesting in rockshelters throughout the Quaternary period, so it is likely that non-human processes explain the relative abundance of *Macropus* sp teeth at Marillana A. Carnivores in the inland Pilbara include dingoes and quolls (Brown 1987:10) and rock engravings suggest that thylacines may also have inhabited the area in the past (Brown 1983). The presence of these predators and the absence of any evidence of human modification of the bone suggest that mammalian carnivores were the primary agents behind the modification of the faunal assemblage at Marillana A.

At Marillana A the concentration of soluble salts is highest in stratigraphic units one and two (figure 4.15). Soluble salt concentration was not analysed for square 11A because no sediment samples were available. This suggests a higher intensity of occupation during these units than units three and four, but leaching of salts from surface material may also have contributed to this distribution. My interpretation of soluble salt concentration as an indicator of the frequency of hearth fires in stratigraphic units one and two is supported by Strawbridge's section drawing that records six ash layers in stratigraphic unit two.

Figure 4.15 Soluble salt concentration at Marillana A square 9B

SU = stratigraphic unit



During the particle size analysis I observed high quantities of small milky white crystals in excavation units 21, 22, 24 and 27 that I suspected to be gypsum ($CaSO_4.2H_2O$). Gypsum is a salt that is found as an evaporite in clay soils and in calcareous soils throughout the Pilbara. X-ray fluorescence analysis of sediments from these spits showed higher concentrations of calcium and sulphur compared to other spits (figures 4.16-4.17), suggesting that the crystals were gypsum and the salts in other spits were not. This evidence suggests that the high concentration of soluble salts over excavation units 21 to 27 may result from the reduced sedimentation and increased erosion during the roof fall period rather than the combustion of organic material. On the other hand, the low solubility of gypsum in water (Courty *et al.* 1989:171) suggests that other more soluble salts may also be present in excavation units 21-27 that were not detected by XRF analysis.

Figure 4.16 Total calcium concentration in sediments at Marillana A square 9B (expressed as %CaO)

SU = stratigraphic unit

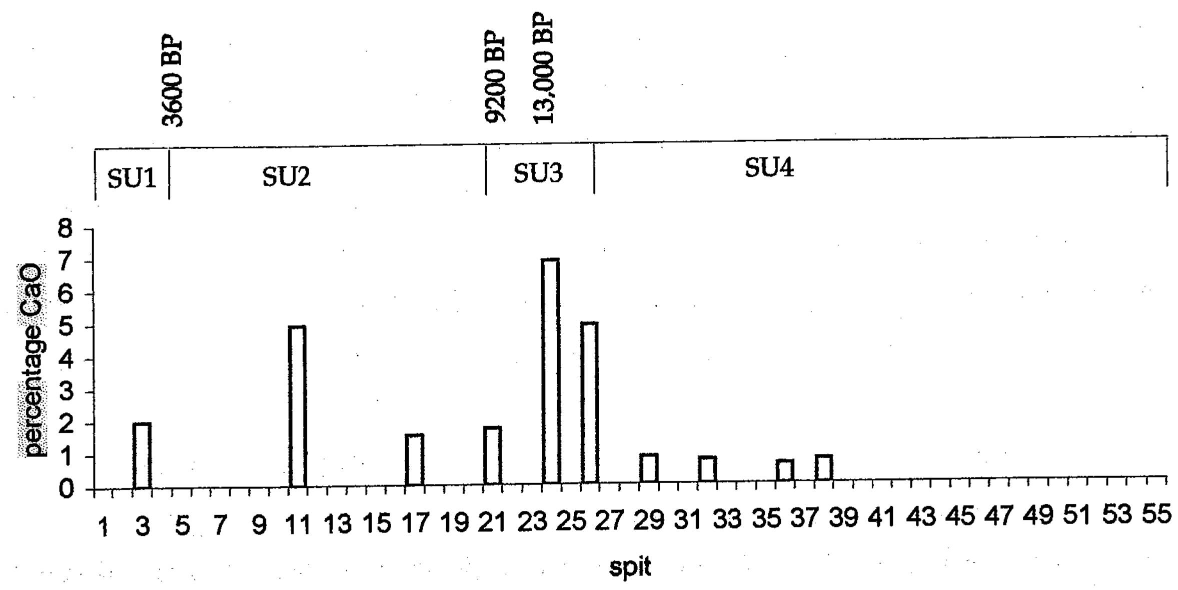
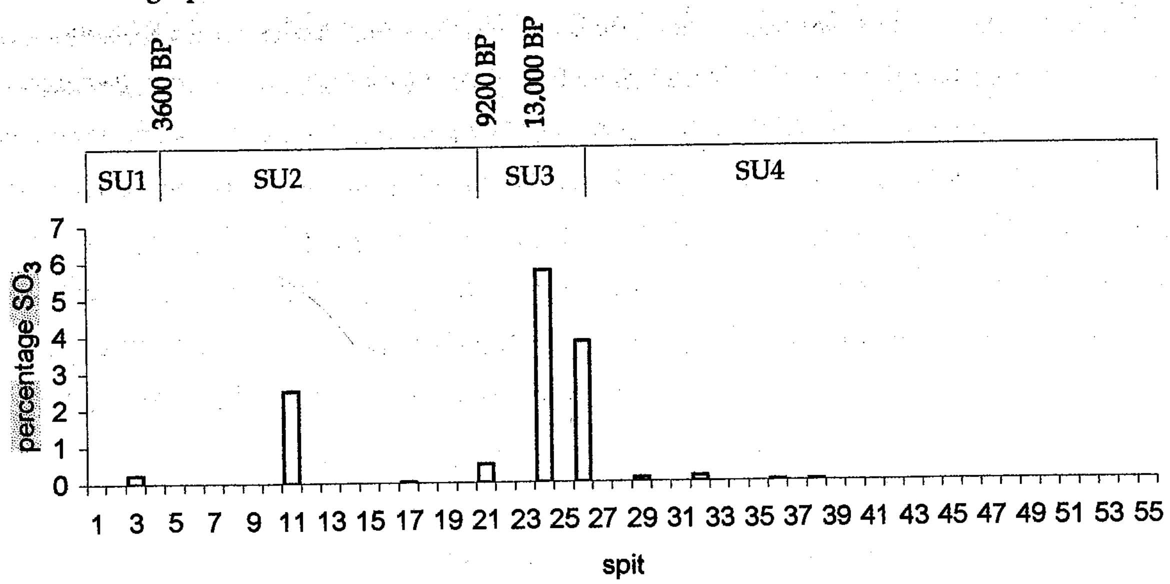


Figure 4.17 Total sulphur concentration in sediments at Marillana A square 9B (expressed as %SO_3

SU = stratigraphic unit



To summarise, the organic material and soluble salt evidence from Marillana A together suggest that occupation intensity was highest after 9200±200 BP in stratigraphic units one and two, but these measures are not unambiguous indicators of human activity. The fragmentation of faunal remains at Marillana

A results from mammalian carnivore activity and is probably unrelated to human activity. The distribution of charcoal is probably due to humans because they coincide with high concentrations of other organic material and the discrete lenses in the section drawings. The preservation of sedimentary and soil organic matter is influenced by preservation conditions and the slow rates of sedimentation in the lower unit may contribute to the low quantities of organic materials in these units.

Stone artefacts

The stone tool assemblage is a further strand of evidence to measure changes in the intensity of occupation at Marillana A and is not subject to the same sort of decay from exposure during slow rates of sedimentation as organic matter. Figures 4.18-4.19 shows number of artefacts per cubic metre of sediment per spit (excavation unit) in square 9A (n=1227) and square 11B (n=407). The majority of stone artefacts at Marillana A are discarded after about 9200±200 BP. Figure 4.18 shows that stone artefact discard is highest in stratigraphic unit two, between 3630±70 BP and 9200±200 BP. Between 9200 BP and 3630 BP the rate of artefact discard is 17.7 artefacts per hundred years. The peak of occupation intensity, measured by artefact discard, occurs near 3630±70 BP and declines rapidly thereafter. There are very few stone artefacts discarded in the roof-fall unit (excavation units 21-26) between 9200 BP and 13,170 BP, and also few artefacts discarded before 13,167±89 BP, suggesting that occupation was not intensive during these periods. The rate of artefact between 9200 BP and 13,170 BP is 0.5 artefacts per hundred years. Although the two squares are difficult to compare because of the differences in excavation unit depths, the similar patterns in the two squares suggests that they represent repeated patterns of behaviour rather than localised and isolated events.

The very small number of artefacts in stratigraphic unit three confirms that there was not a major period of erosion between 9200±200 BP and 13,167±89 BP that destroyed deposits that accumulated over this time. A period of erosion in unit three is unlikely because there is no lag deposit of artefacts that would have accumulated at the boundary between stratigraphic units three and four (excavation units 26-27).

Figure 4.18 Stone artefact discard at Marillana A square 9B (n = 1227)

SU = stratigraphic unit

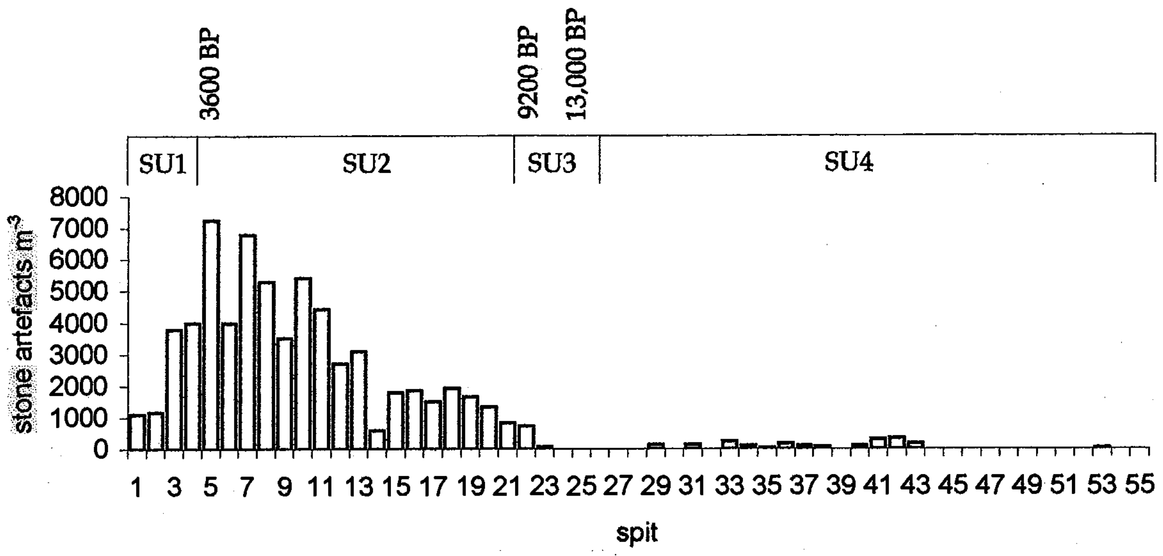
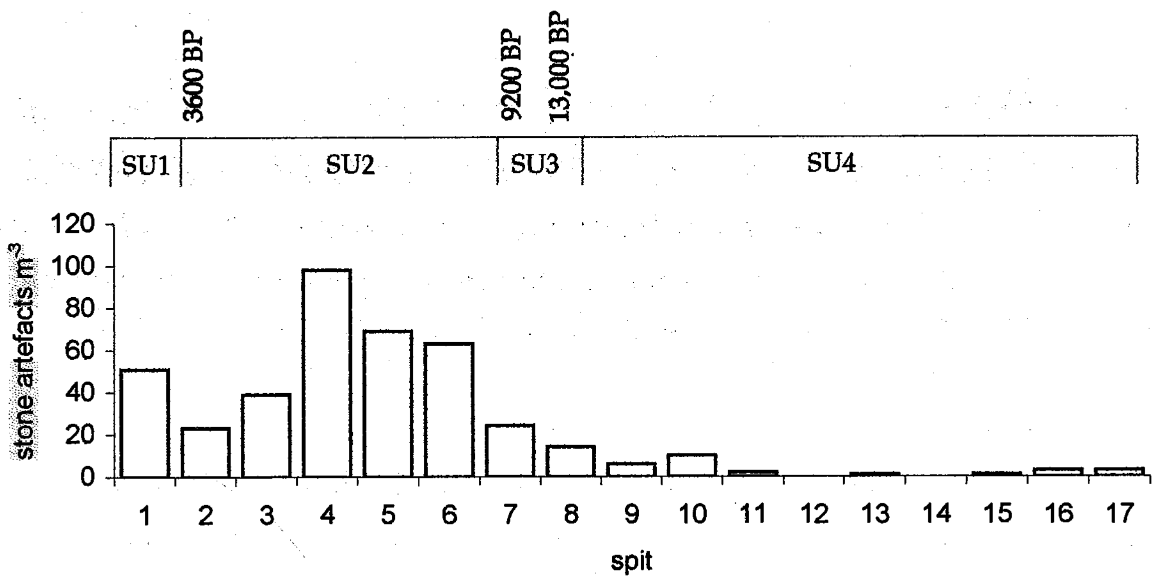


Figure 4.19 Stone artefact discard at Marillana A square 11A (n = 407)

SU = stratigraphic unit



To link artefact discard to occupation intensity, I investigated the influence of changes in post-depositional processes, changes in artefact manufacture and changes in the function of the site. These variables are important here because a change in one variables could alter the discard rate of artefacts without any change in occupation intensity. I analysed breakage patterns to identify changes in post-depositional processes and technological, metric and raw material variables to identify changes in artefact manufacture and changes in the function of the site. The analysis of these variables was undertaken on stone artefacts from square 9B only. Square 9B was excavated in smaller spits than 11A allowing higher resolution in detecting changes between stratigraphic

units. In addition, the depth of unit four in square 11A is half that of square 9B because of uneven baserock, making comparison between stratigraphic unit four and other units between the two squares invalid.

Post-depositional change

Table 4.2 shows the numbers of each debitage type for each stratigraphic unit in square 9B. Angular fragments make up nearly half of the assemblage in each unit, followed by flake fragments. The main difference between the four units is in unit three where there are no complete flakes or broken flakes. This is probably because unit three is a roof-fall unit and the large rocks covering the floor of the shelter made it an uncomfortable place to use and discard stone artefacts.

Table 4.2 Debitage analysis of stone artefacts from Marillana A square 9B

SU = stratigraphic unit
n = number of artefacts
$\%_1$ = percent of total artefacts recovered from the site
$\%_2$ = percent of total artefacts recovered from stratigraphic unit

SU	total artefacts		complete flake		broken flake (long)		broken flake (trans)		flake fragment		angular piece	
	n	$\%_1$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$
1	219	17.8	32	14.6	0	0.0	6	2.7	70	32.0	111	50.7
2	903	73.6	104	11.5	1	0.1	10	1.1	334	37.0	454	50.3
3	48	3.9	0	0.0	0	0.0	0	0.0	8	16.7	40	83.3
4	57	4.6	10	17.5	0	0.0	1	1.8	17	29.8	29	50.9

Chi-square tests summarised in table 4.3 show that the differences in the proportions of debitage types observed in stratigraphic units one, two, three and four are not significant. The absence of a significant difference, even with no complete flakes or broken flakes in stratigraphic unit three, is probably due to the small numbers of artefacts in each unit.

Table 4.3 Chi-square tests on differences in the numbers of each debitage type between stratigraphic units at Marillana A square 9B

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

SU	χ^2	df	$p(H_0)$	reject H_0?
1:2	1.401	3	0.705	no
2:3	0.595	3	0.897	no
3:4	2.130	3	0.545	no

I identified a conjoin between two angular fragments of chalcedony in the northwest quadrant of excavation unit nine. The close proximity of the two pieces suggests that stratigraphic integrity around excavation unit nine is high.

This debitage and conjoin evidence presented above suggest that there are no significant changes in the degree of post-depositional processes related to artefact breakage or post-depositional artefact migration throughout the history of occupation of the shelter.

Artefact manufacture

Raw materials

As post-depositional processes have not significantly affected artefact discard, the differences in artefact discard must result from changes in human behaviour. One set of behaviours that may have changed artefact discard are techniques of artefact manufacture. The first variable to examine when investigating changes in artefact manufacture is raw material because raw material properties influence flaking properties measured by technological and metric analyses. I analysed changes in the frequency of the three most abundant raw materials (chert, chalcedony and silcrete) to see if change in raw materials was the cause of the changes in artefact discard at Marillana A.

Table 4.4 shows the numbers of stone artefacts for each raw material found in the four stratigraphic units. Locally available fine-grained silicious materials such as chalcedony, chert and quartz are the most abundant raw materials in each unit. Although immediately available in the rockshelter walls and roof, ironstone and banded ironstone formation (bif) are not as frequently exploited, probably because their flaking properties are less predictable than more siliceous raw materials.

Table 4.4 Raw materials of stone artefacts at Marillana A square 9B

SU= stratigraphic unit
n= number of artefacts
$\%_1$ = percent of total artefacts recovered from the site
$\%_2$ = percent of total artefacts recovered from stratigraphic unit

SU	total artefacts		chalcedony		chert		silcrete		quartz		ironstone		bif		others	
	n	%1	n	%2	n	%2	n	%2	n	%2	n	%2	n	%2	n	%2
1	219	17.8	77	35.2	71	32.4	7	3.2	36	16.4	20	9.1	4	1.8	4	1.8
2	903	73.6	254	28.1	194	21.5	191	21.2	150	16.6	69	7.6	30	3.3	15	1.6
3	48	3.91	1	2.08	4	8.33	18	37.5	5	10.4	11	22.9	7	14.5	2	4.1
4	57	4.65	5	8.77	11	19.3	18	31.6	8	14	9	15.7	0	0	6	10.5

Table 4.5 shows that numbers of chert and non-chert artefacts in stratigraphic units one and two, units one and three and units two and three differ significantly although the strength of association is very weak. The numbers of chert and non-chert artefacts in unit four compared to the other units does not differ significantly. The positive phi values in table 4.5 indicate that the number of chert artefacts increases significantly from unit three to unit two to unit one. In this trend towards greater use of chert for artefact manufacture in the Holocene, Marillana A shows a similar pattern to Newman Orebody XXIX and Newman Rockshelter (Brown 1987:48).

Table 4.5 Chi-square tests on differences in the numbers of chert artefacts between stratigraphic units at Marillana A square 9B

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true
ϕ= Phi coefficient (direction of association)
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

SU	χ^2	df	$p(H_0)$	reject H_0?	ϕ	C_{adj}
1:2	12.504	1	0.0004	yes	0.105	0.145
2:3	4.594	1	0.032	yes	0.513	0.051
3:4	2.558	1	0.109	no	na	na

Table 4.6 shows a significant increase in the numbers of artefacts made from chalcedony over time. The phi and contingency coefficient values for the increase in chalcedony artefacts between units one and two are lesser than those for chert indicating the change in chert artefacts was more pronounced at that time (about 3000 BP). On the other hand, the phi and contingency coefficient

values for the increase in chalcedony between units two and three are greater than those for the increase in chert artefacts indicating that the increase in chalcedony artefacts in more pronounced than the increase in chert artefacts at that time (about 9000 BP).

Table 4.6 Chi-square tests on differences in the numbers of chalcedony artefacts between stratigraphic units at Marillana A square 9B

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true
ϕ= Phi coefficient (direction of association)
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

SU	χ^2	df	$p(H_0)$	reject H_0?	ϕ	C_{adj}
1:2	4.189	1	0.041	yes	0.061	0.084
2:3	15.747	1	7.21×10^{-5}	yes	0.560	0.094
3:4	2.163	1	0.141	no	na	na

Table 4.7 indicates that silcrete shows the opposite trend to chert and chalcedony. The phi values indicates that silcrete becomes significantly more abundant after 9000 BP but less abundant after 3000 BP. The low contingency coefficient values indicate that these changes, like the changes in other raw materials, are not of a high magnitude.

Table 4.7 Chi-square tests on differences in the numbers of silcrete artefacts between stratigraphic units at Marillana A square 9B

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true
ϕ= Phi coefficient (direction of association)
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

SU	χ^2	df	$p(H_0)$	reject H_0?	ϕ	C_{adj}
1:2	39.099	1	4.03×10^{-10}	yes	-0.186	0.254
2:3	7.103	1	0.007	yes	0.584	0.063
3:4	0.405	1	0.524	no	na	na

To summarise the major changes in raw materials at Marillana A, the proportions of artefacts made from chalcedony and chert increase over time while the proportions of artefacts made from silcrete increase at about 9000 BP and then decrease at about 3000 BP. A change in raw materials may have

accompanied a change in artefact manufacturing techniques, resulting in a change in artefact discard independent of a change in occupation intensity. The following section examines whether the switch from more to less accessible raw materials required different technological strategies to conserve raw material, resulting in less artefact discard.

Technological variables

To identify changes in raw material conservation strategies I looked for changes in technological and metric variables in the three most abundant raw materials (chert, chalcedony and silcrete) between the stratigraphic units. Sample sizes for each raw material are small and it is possible that the samples analysed here reflect single episodes rather than represent typical artefact manufacturing behaviour. To minimise the effect of atypical episodes I identify technological change only if significant changes in multiple technological variables indicate a change in the same direction.

Table 4.8 shows that there are no substantial or statistically significant changes in the manufacture of chert flakes at Marillana A. Table 4.9 and figures 4.20-4.23 shows that chert artefacts do not change in size over time, but there are increases in the mass, thickness and platform width and thickness of complete flakes at 3000 BP. This may reflect less efficient use of chert as it increases in abundance.

Table 4.8 Summary of technological analysis of chert flakes from Marillana A square 9B

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit 1		2		4		significant change in variable?			
	years BP	0-3000		3000-9000		>13,000					
	number of chert complete flakes	8		17		3					
	% of all flakes that are chert	25		16.3		30					
		n	%	n	%	n	%	reject H_0 ?	C_{adj}	when?	direction?
termination	feather	6	75	16	94.1	2	66.7	no	na	na	na
platform surface	flat	3	37.5	8	47.1	1	33.3	no	na	na	na
	facetted	5	62.5	9	52.9	2	66.7	no	na	na	na
	cortical	0	0	0	0	0	0	no	na	na	na
platform type	wide	8	100	12	70.6	2	66.7	no	na	na	na
	focalised	0	0	4	23.5	1	33.3	no	na	na	na
	gull	0	0	1	5.9	0	0	na	na	na	na
overhang removal	flakes with overhang removal	3	37.5	9	52.9	3	100	no	na	na	na
reduction level	flakes with >1 dorsal flake scar	8	100	4	23.5	1	33.3	no	na	na	na
	flakes with distal and lateral flake scars	1	12.5	2	11.7	0	0	no	na	na	na
	flakes with <10 cortex	6	75	15	88.2	2	66.7	no	na	na	na
	flakes with 10-50 cortex	2	25	2	11.7	1	33.3	no	na	na	na
	flakes with >50 cortex	0	0	0	0	0	0	no	na	na	na

Table 4.9 Summary of metric analysis of chert flakes from Marillana A square 9B

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t-tests

		stratigraphic unit	1	2	3	4
		time period years BP	0-3000	3000-9000	9000-13,000	>13,000
		total number of chert artefacts	71	194	4	11
		total number of chert flakes	8	17	0	3
mass of total artefacts		mean (g)	0.33	0.30	0.24	0.32
	significant change?	t	0.490	-0.610	0.439	na
		$p(H_0)$	0.625	0.543	0.668	na
		reject H_0?	no	no	no	na
flake length		mean (mm)	13.33	11.00	0.00	10.73
	significant change?	t	1.203	-0.314	na	na
		$p(H_0)$	0.241	0.757	na	na
		reject H_0?	no	no	na	na
flake width		mean (mm)	14.77	8.94	0.00	11.03
	significant change?	t	1.756	-0.860	na	na
		$p(H_0)$	0.092	0.401	na	na
		reject H_0?	no	no	na	na
flake thickness		mean (mm)	3.75	2.45	0.00	2.03
	significant change?	t	2.156	-0.231	na	na
		$p(H_0)$	0.042	0.820	na	na
		reject H_0?	yes - increase	no	na	na
flake mass		mean (g)	1.19	0.49	0.00	0.27
	significant change?	t	2.367	-0.318	na	na
		$p(H_0)$	0.027	0.754	na	na
		reject H_0?	yes - increase	no	na	na
flake platform width		mean (mm)	10.29	5.71	0.00	3.13
	significant change?	t	2.190	1.410	na	na
		$p(H_0)$	0.039	0.176	na	na
		reject H_0?	yes - increase	no	na	na
flake platform thickness		mean (mm)	3.63	1.60	0.00	1.27
	significant change?	t	4.231	0.168	na	na
		$p(H_0)$	0.0003	0.868	na	na
		reject H_0?	yes - increase	no	na	na

Figure 4.20 Frequency distribution of chert flake lengths in unit one of Marillana A square 9B

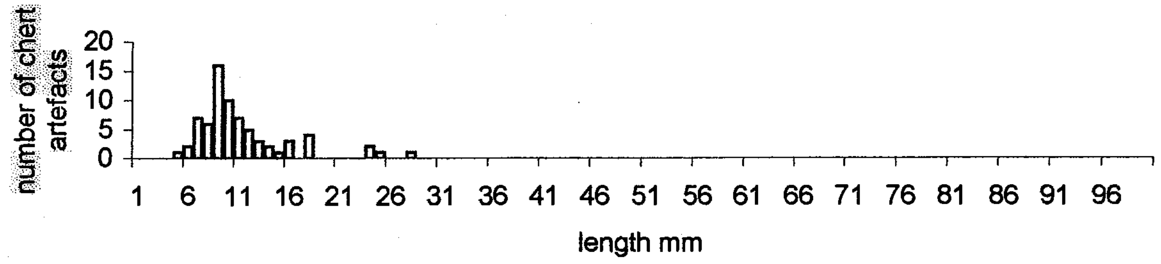


Figure 4.21 Frequency distribution of chert flake lengths in unit two of Marillana A square 9B

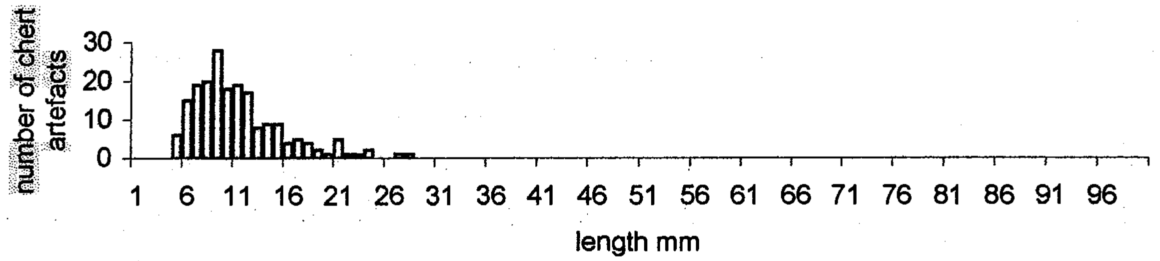


Figure 4.22 Frequency distribution of chert flake lengths in unit three of Marillana A square 9B

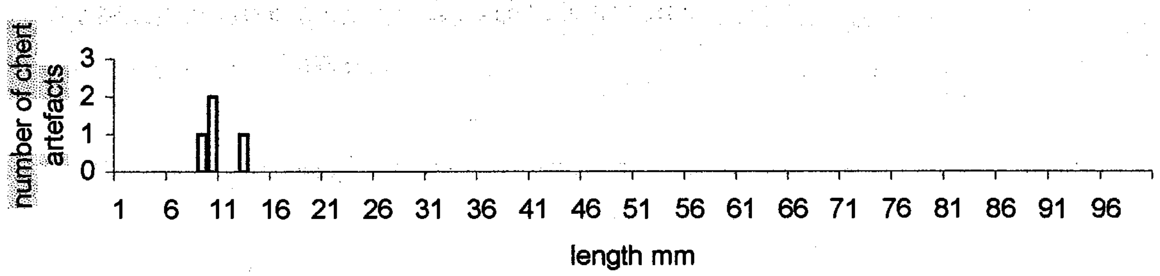


Figure 4.23 Frequency distribution of chert flake lengths in unit four of Marillana A square 9B

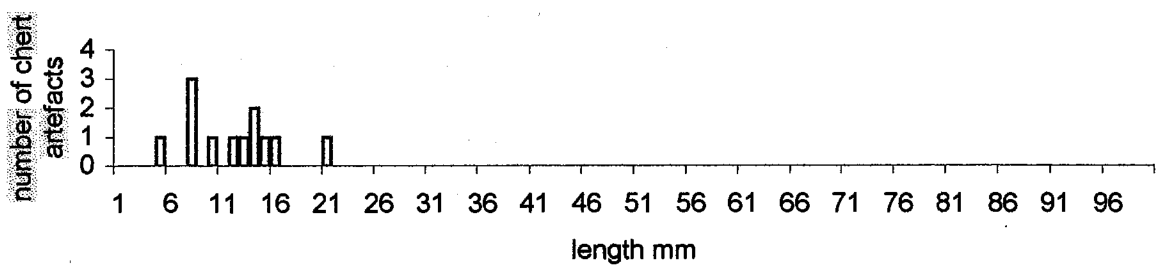


Table 4.10 and table 4.12 show that the manufacture of chalcedony and silcrete flakes does not change over time. Chalcedony is the most abundant raw material after 3000 BP but there are no technological changes that suggest a change in its manufacture. The significant decreases at 3000 BP in chalcedony flakes with facetted platforms and in silcrete flakes with more than one dorsal flake scar are not suggestive of changes in manufacturing technology because they do not coincide with similar indicators of less efficient production, such as increased dorsal cortex, increased size and increased cortical platforms (table 4.11 and 4.13). Table 4.11 and figures 4.24-4.27 show that there are no significant changes in the size of chalcedony artefacts. Silcrete artefacts decrease in size significantly at 13,000 BP and silcrete flakes decrease in size at 9000 BP (table 4.13, figures 4.28-4.31).

Artefacts made from raw materials other than chert, chalcedony and silcrete show no change in manufacturing technology (table 4.14, figures 4.32-4.35). I analysed artefacts made from raw materials other than chert, chalcedony and silcrete together because they are only represented by a few pieces for each raw material type, making statistical comparisons invalid. The decrease in feather terminations and the increase in flakes with more than one flake scar at 3000 BP may indicate an increased intensity of core reduction, but the absence of a change in flake platform surface or any reduction in artefact and flake size (table 4.14, figures 4.32-4.35) at this time suggests that no change in technology has occurred.

In summary, there are no changes in the raw materials and technology of artefact manufacture, such as less efficient use of abundant raw materials though lower levels of reduction, that might explain an increase in artefact discard at 3000-9000 BP. Similarly, the decrease in discard after 3000 BP is not accompanied by indicators of restricted raw material supply and increased levels of reduction.

Table 4.10 Summary of technological analysis of chalcedony flakes from Marillana A square 9B

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

	stratigraphic unit										
		1		2		4					
	years BP	0-3000		3000-9000		>13,000					
	number of chalcedony complete flakes	16		35		1					
	% of all flakes that are chalcedony	50		33.6		10					
								significant change in variable?			
		n	%	n	%	n	%	reject H_0?	C_{adj}	when?	direction?
termination	feather	12	75	26	74.3	1	100	no	na	na	na
platform	flat	11	68.7	14	40	0	0	no	na	na	na
	facetted	4	25	20	57.1	1	100	yes	0.401	SU1:2 3000 BP	decrease
	cortical	1	6.3	1	2.9	0	0	no	na	na	na
platform type	wide	11	68.7	28	80	1	100	no	na	na	na
	focalised	1	6.3	7	20	0	0	no	na	na	na
	gull	4	25	0	0	0	0	na	na	na	na
overhang removal	flakes with overhang removal	6	37.5	13	37.1	1	100	no	na	na	na
reduction level	flakes with >1 dorsal flake scar	5	31.2	10	28.5	1	100	no	na	na	na
	flakes with distal and lateral flake scars	0	0	0	0	0	0	no	na	na	na
	flakes with <10 cortex	14	87.5	31	88.5	0	0	no	na	na	na
	flakes with 10-50 cortex	2	12.5	4	11.5	1	100	no	na	na	na
	flakes with >50 cortex	0	0	0	0	0	0	no	na	na	na

Table 4.11 Summary of metric analysis of chalcedony flakes from Marillana A square 9B

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t- tests

		stratigraphic unit	1	2	3	4
		time period years BP	0-3000	3000-9000	9000-13,000	>13,000
		total number of chalc artefacts	77	254	1	5
		total number of chalc flakes	16	35	0	1
mass of total artefacts		mean (g)	0.40	0.51	0.09	0.73
	significant change?	t	0.409	0.410	na	na
		$p(H_0)$	0.683	0.682	na	na
		reject H_0?	no	no	na	na
flake length		mean (mm)	8.51	11.48	0.00	15.00
	significant change?	t	-0.182	na	na	na
		$p(H_0)$	0.856	na	na	na
		reject H_0?	no	na	na	na
flake width		mean (mm)		9.99	0.00	25.80
	significant change?	t	-0.865	na	na	na
		$p(H_0)$	0.391	na	na	na
		reject H_0?	no	na	na	na
flake thickness		mean (mm)	1.84	2.95	0.00	6.20
	significant change?	t	-1.082	na	na	na
		$p(H_0)$	0.285	na	na	na
		reject H_0?	no	na	na	na
flake mass		mean (g)	0.43	0.78	0.00	2.10
	significant change?	t	-0.281	na	na	na
		$p(H_0)$	0.780	na	na	na
		reject H_0?	no	na	na	na
flake platform width		mean (mm)	6.32	9.70	0.00	7.01
	significant change?	t	0.811	na	na	na
		$p(H_0)$	0.421	na	na	na
		reject H_0?	no	na	na	na
flake platform thickness		mean (mm)	1.70	2.46	0.00	4.00
	significant change?	t	-0.600	na	na	na
		$p(H_0)$	0.551	na	na	na
		reject H_0?	no	na	na	na

Figure 4.24 Frequency distribution of chalcedony flake lengths in unit one of Marillana A square 9B

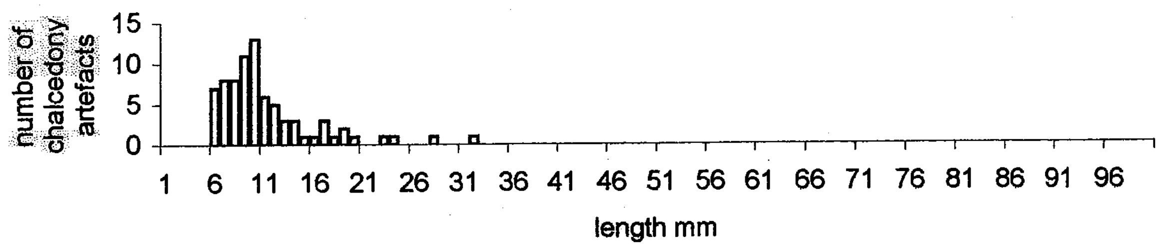


Figure 4.25 Frequency distribution of chalcedony flake lengths in unit two of Marillana A square 9B

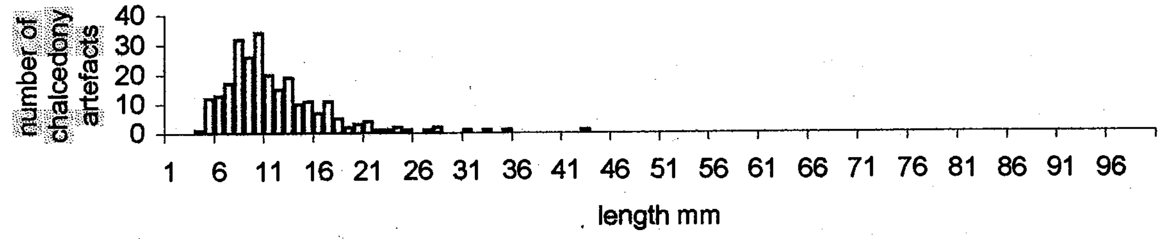


Figure 4.26 Frequency distribution of chalcedony flake lengths in unit three of Marillana A square 9B

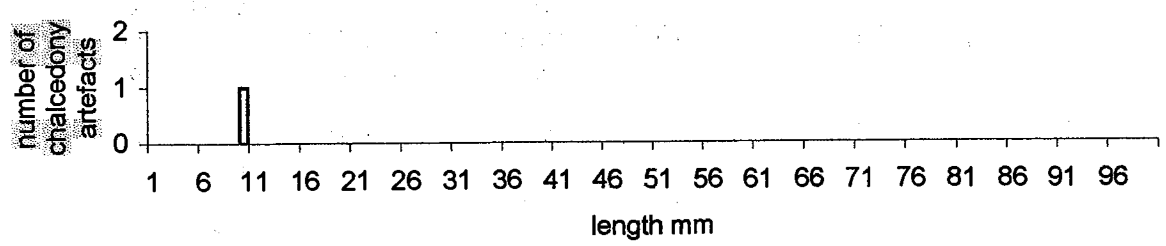


Figure 4.27 Frequency distribution of chalcedony flake lengths in unit four of Marillana A square 9B

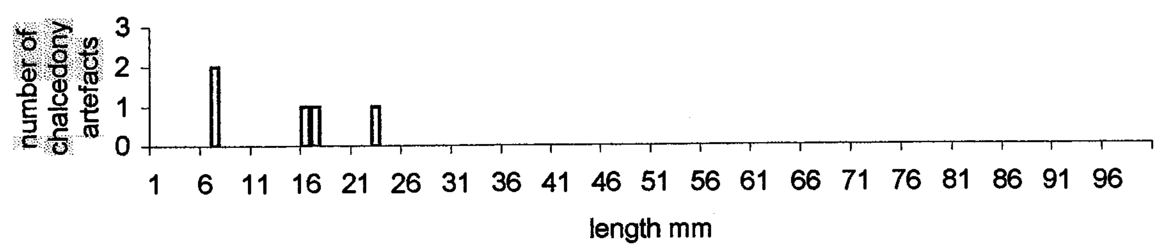


Table 4.12 Summary of technological analysis of silcrete flakes from Marillana A square 9B

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit									
		1		2		4					
	years BP	0-3000		3000-9000		>13,000					
	number of silcrete complete flakes	3		35		6					
	% of all flakes that are silcrete	9.4		33.6		60					
								significant change in variable?			
		n	%	n	%	n	%	reject Ho?	C_{adj}	when?	direction?
termination	feather	3	100	31	88.6	5	83.3	no	na	na	na
platform	flat	3	100	16	45.7	3	50	no	na	na	na
	facetted	0	0	18	51.5	2	33.3	no	na	na	na
	cortical	0	0	1	2.8	1	16.7	no	na	na	na
platform type	wide	3	100	27	77.1	6	100	na	na	na	na
	focalised	0	0	5	14.3	0	0	na	na	na	na
	gull	0	0	3	8.6	0	0	na	na	na	na
overhang removal	flakes with overhang removal	0	0	18	51.4	3	50	no	na	na	na
reduction level	flakes with >1 dorsal flake scar	0	0	4	11.4	4	66.7	yes	0.351	SU2:4 9000-13,000 BP	decrease
	flakes with distal and lateral flake scars	0	0	0	0	0	0	no	na	na	na
	flakes with <10 cortex	3	100	30	85.7	4	66.7	no	na	na	na
	flakes with 10-50 cortex	0	0	5	14.3	2	33.3	no	na	na	na
	flakes with >50 cortex	0	0	0	0	0	0	no	na	na	na

Table 4.13 Summary of metric analysis of silcrete flakes from Marillana A square 9B

t= **t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)**

$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t- tests

		1	2	3	4
	stratigraphic unit	1	2	3	4
	time period BP	0-3000	3000-9000	9000-13,000	>13,000
	total number of silc artefacts	7	191	18	18
	total number of silc flakes	3	35	0	6
mass of total artefacts	mean (g)	0.52	0.74	1.29	2.54
significant change?	t	-0.318	0.552	-2.300	na
	$p(H_0)$	0.750	0.582	0.028	na
	reject H_0?	no	no	yes - decrease	na
flake length	mean (mm)	6.87	13.45	0.00	27.20
significant change?	t	-1.908	-3.805	na	na
	$p(H_0)$	0.064	0.0005	na	na
	reject H_0?	no	yes - decrease	na	na
flake width	mean (mm)	7.77	13.00	0.00	19.17
significant change?	t	-1.421	-2.086	na	na
	$p(H_0)$	0.164	0.044	na	na
	reject H_0?	no	yes - decrease	na	na
flake thickness	mean (mm)	1.33	2.87	0.00	5.17
significant change?	t	-1.347	-2.716	na	na
	$p(H_0)$	0.186	0.010	na	na
	reject H_0?	no	yes - decrease	na	na
flake mass	mean (g)	0.12	1.25	0.00	3.14
significant change?	t	-1.397	-2.975	na	na
	$p(H_0)$	0.171	0.005	na	na
	reject H_0?	no	yes - decrease	na	na
flake platform width	mean (mm)	4.90	8.80	0.00	10.83
significant change?	t	-1.173	-1.311	na	na
	$p(H_0)$	0.249	0.198	na	na
	reject H_0?	no	no	na	na
flake platform thickness	mean (mm)	1.63	2.38	1.00	2.98
significant change?	t	-0.279	-1.574	na	na
	$p(H_0)$	0.782	0.124	na	na
	reject H_0?	no	no	na	na

Figure 4.28 Frequency distribution of silcrete flake lengths in unit one of Marillana A square 9B

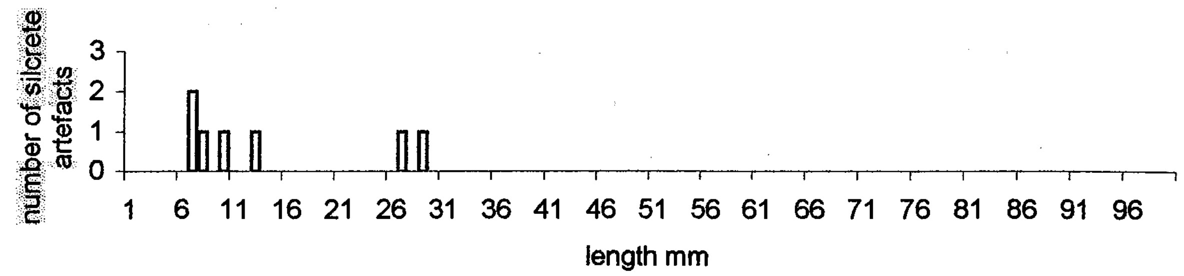


Figure 4.29 Frequency distribution of silcrete flake lengths in unit two of Marillana A square 9B

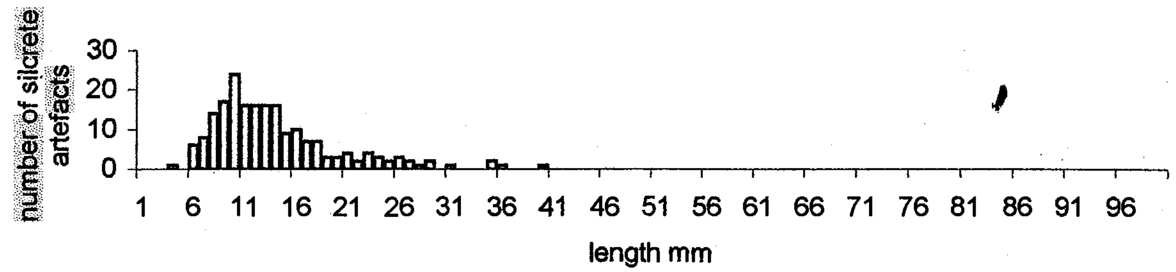


Figure 4.30 Frequency distribution of silcrete flake lengths in unit three of Marillana A square 9B

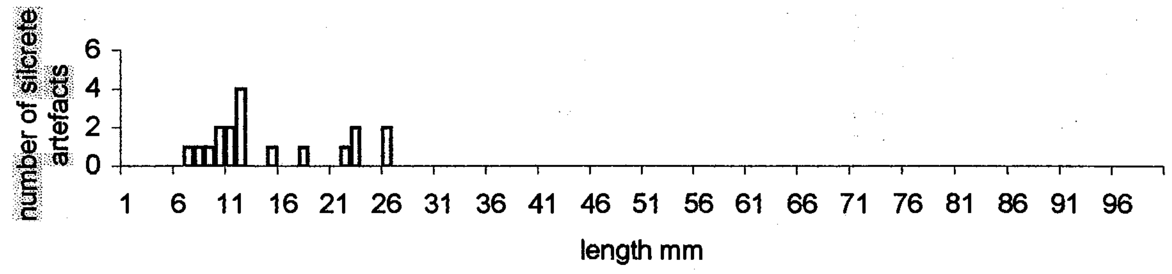


Figure 4.31 Frequency distribution of silcrete flake lengths in unit four of Marillana A square 9B

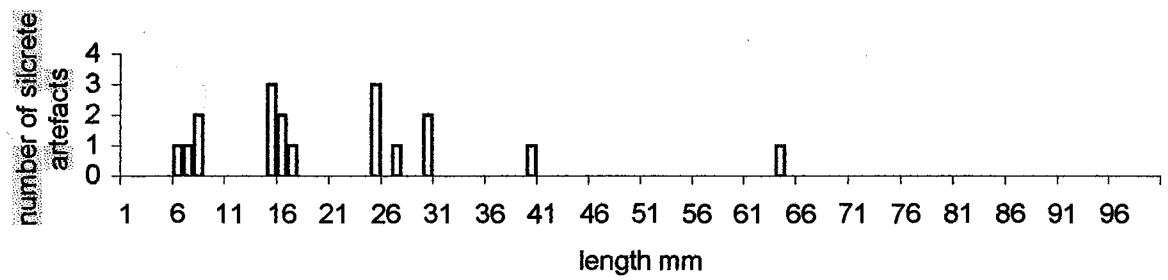


Table 4.14 Summary of technological analysis of flakes made from raw materials other than chert, chalcedony and silcrete from Marillana A square 9B

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit 1		2		4		significant change in variable?			
	years BP	0-3000		3000-9000		>13,000					
	number of other complete flakes	5		17		0					
	% of all flakes that are other raw materials	15.6		16.4		0					
		n	%	n	%	n	%	reject Ho?	C_{adj}	when?	direction?
termination	feather termination	2	40	15	88.2	0	0	yes	0.614	SU1:2 3000 BP	decrease
platform	flat	1	20	6	35.3	0	0	no	na	na	na
	facetted	3	60	11	64.7	0	0	no	na	na	na
	cortical	1	20	0	0	0	0	na	na	na	na
platform type	wide	4	80	15	88.2	0	0	no	na	na	na
	focalised	1	20	2	11.8	0	0	no	na	na	na
	gull	0	0	0	0	0	0	no	na	na	na
overhang removal	flakes with overhang removal	2	40	3	17.6	0	0	no	na	na	na
reduction level	flakes with >1 dorsal flake scar	3	60	2	11.7	0	0	yes	0.614	SU1:2 3000 BP	increase
	flakes with distal and lateral flake scars	0	0	0	0	0	0	no	na	na	na
	flakes with <10 cortex	5	100	15	88.2	0	0	na	na	na	na
	flakes with 10-50 cortex	0	0	2	11.8	0	0	na	na	na	na
	flakes with >50 cortex	0	0	0	0	0	0	no	na	na	na

Table 4.15 Summary of metric analysis of flakes made from raw materials other than chert, chalcedony and silcrete from Marillana A square 9B

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t- tests

		stratigraphic unit	1	2	3	4
		time period years BP	0-3000	3000-9000	9000-13,000	>13,000
		total number of artefacts	64	264	25	23
		total number of flakes	5	17	0	0
mass of total artefacts		mean (g)	0.86	3.48	2.41	8.94
	significant change?	t	-1.312	-3.137	-0.112	na
		$p(H_0)$	0.190	0.002	0.911	na
		reject H_0?	no	yes - increase	no	na
flake length		mean (mm)	10.00	11.15	na	na
	significant change?	t	-0.300	na	na	na
		$p(H_0)$	0.767	na	na	na
		reject H_0?	no	na	na	na
flake width		mean (mm)	6.22	9.68	na	na
	significant change?	t	-1.318	na	na	na
		$p(H_0)$	0.202	na	na	na
		reject H_0?	no	na	na	na
flake thickness		mean (mm)	1.60	2.39	na	na
	significant change?	t	-0.721	na	na	na
		$p(H_0)$	0.479	na	na	na
		reject H_0?	no	na	na	na
flake mass		mean (g)	0.13	0.70	na	na
	significant change?	t	-0.892	na	na	na
		$p(H_0)$	0.383	na	na	na
		reject H_0?	no	na	na	na
flake platform width		mean (mm)	3.70	6.19	0.00	0.00
	significant change?	t	-0.851	na	na	na
		$p(H_0)$	0.405	na	na	na
		reject H_0?	no	na	na	na
flake platform thickness		mean (mm)	1.56	2.46	0.00	0.00
	significant change?	t	-0.715	na	na	na
		$p(H_0)$	0.483	na	na	na
		reject H_0?	no	na	na	na

Figure 4.32 Frequency distribution of lengths of flakes made from raw materials other than chert, chalcedony and silcrete in unit one of Marillana A square 9B

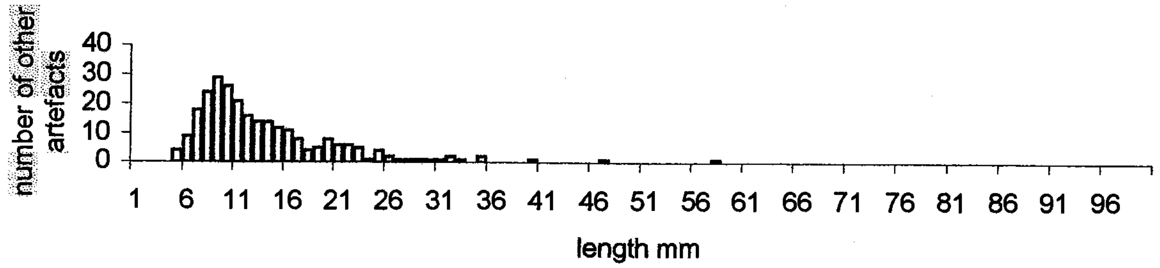


Figure 4.33 Frequency distribution of lengths of flakes made from raw materials other than chert, chalcedony and silcrete in unit two of Marillana A square 9B

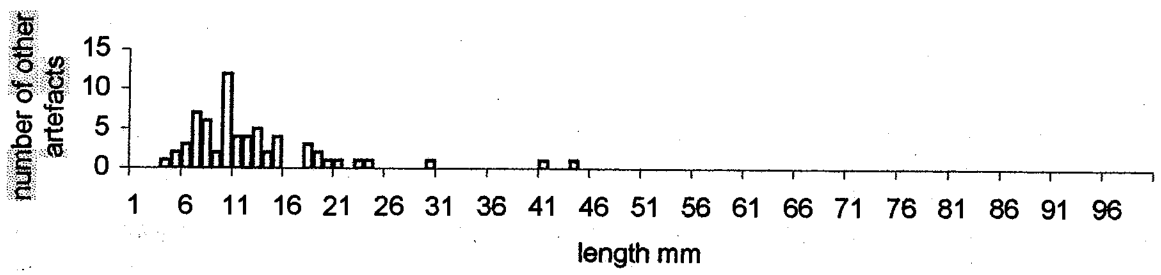


Figure 4.34 Frequency distribution of lengths of flakes made from raw materials other than chert, chalcedony and silcrete in unit three of Marillana A square 9B

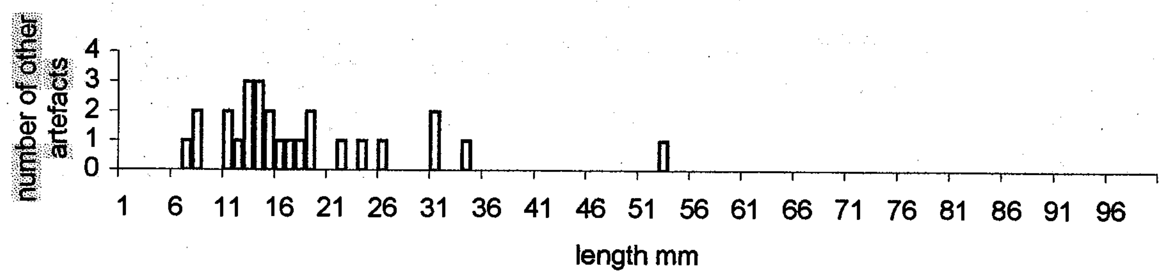
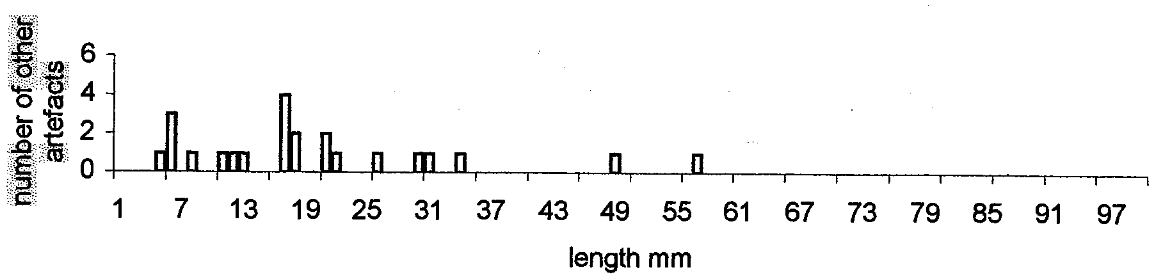


Figure 4.35 Frequency distribution of lengths of flakes made from raw materials other than chert, chalcedony and silcrete in unit four of Marillana A square 9B



Change in the function of the site

Table 4.16 shows the numbers of all artefacts with secondary working. The highest numbers of worked artefacts are discarded at 3000-9000 BP, but this is also the period when the highest numbers of all artefacts were discarded and the proportion of worked artefacts in this period is *lower* than the periods 0-3000 BP and >13,000 BP. The highest proportion of worked artefacts are discarded at >13,000 BP. This suggests an inverse relationship between total artefact discard and discard of worked artefacts.

Table 4.16 Summary of all artefacts with evidence of secondary working and cores from Marillana A square 9B

χ^2= chi-square
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3	4
years BP	0-3000	3000-9000	9000-13,000	>13,000
total number of artefacts	219	903	48	57
total number of artefacts with retouch/usewear	13	20	0	5
number of artefacts with retouch/usewear that are backed	1	1	0	0
total number of cores	0	3	0	0
% of artefacts with retouch/usewear	5.9	2.2	0.0	8.8
χ^2	9.081	9.089	na	na
$p(H_0)$	0.003	0.003	na	na
reject H_0?	yes - increase	yes - decrease	na	na

If the data in table 4.16 is interpreted as evidence of the curation-mobility relationship discussed in chapter three, then the frequency of residential moves was significantly reduced during the period 3000-9000 BP. As discussed in chapter three, I do not believe that the curation-mobility relationship is the most convincing hermeneutic for patterns of curation in the inland Pilbara. It is possible that raw material mechanics and raw material nodule size, as well as isochrestic variation, were influential in determining curation patterns. Tables 4.17 to 4.20 show proportions of secondary working and cores for chert, chalcedony, silcrete and other raw materials. Chert and chalcedony artefacts with secondary working only occur after 9000 BP (tables 4.17-4.18) when these raw materials increase in abundance. Chert artefacts with secondary working are most abundant after 3000 BP, when chert is at its most abundant (table 4.17, table 4.4). Both of the backed artefacts are made from chert, one was recovered from excavation unit four and another from excavation unit thirteen (dates for these units were not obtained because of limited resources and time). Prior to 9000 BP, silcrete artefacts are the only artefacts with secondary working and before 13,000 BP silcrete is the most frequently worked raw material of any period (table 4.19). There are no silcrete artefacts with secondary working after 3000 BP (table 4.19). Raw materials other than chert, chalcedony and silcrete are retouched only after 9000 BP (table 4.20).

Table 4.17 Summary of chert artefacts with evidence of secondary working and cores from Marillana A square 9B

χ^2= chi-square
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3	4
years BP	0-3000	3000-9000	9000-13,000	>13,000
total number of chert artefacts	71	194	4	11
total number of chert artefacts with retouch/usewear	8	7	0	0
number of chert artefacts with retouch/usewear that are backed	1	1	0	0
total number of chert cores	0	0	0	0
% of chert artefacts with retouch/usewear	11.3	3.6	0	0
χ^2	5.710	na	na	na
$p(H_0)$	0.017	na	na	na
significant change?	yes - increase	na	na	na

Table 4.18 Summary of chalcedony artefacts with evidence of secondary working and cores from Marillana A square 9B

χ^2= chi-square
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3	4
years BP	0-3000	3000-9000	9000-13,000	>13,000
total number of chalc artefacts	77	254	1	5
total number of chalc artefacts with retouch/usewear	2	6	0	0
number of chalc artefacts with retouch/usewear that are backed	0	0	0	0
total number of chalc cores	0	1	0	0
% of chalc artefacts with retouch/usewear	2.6	2.4	0	0
χ^2	0.014	na	na	na
$p(H_0)$	0.906	na	na	na
significant change?	no	na	na	na

Table 4.19 Summary of silcrete artefacts with evidence of secondary working and cores from Marillana A square 9B

χ^2= chi-square
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3	4
years BP	0-3000	3000-9000	9000-13,000	>13,000
total number of silc artefacts	7	191	18	18
total number of silc artefacts with retouch/usewear	0	4	0	5
number of silc artefacts with retouch/usewear that are backed	0	0	0	0
total number of silc cores	0	2	0	0
% of silc artefacts with retouch/usewear	0	2.1	0	27.8
χ^2	na	26.33233	na	na
$p(H_0)$	na	2.87×10^{-7}	na	na
significant change?	na	yes - decrease	na	na

Table 4.20 Summary of artefacts made from raw materials other than chert, chalcedony and silcrete with evidence of secondary working and cores from Marillana A square 9B

χ^2= chi-square
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3	4
years BP	0-3000	3000-9000	9000-13,000	>13,000
total number of artefacts	64	264	25	23
total number of artefacts with retouch/usewear	3	3	0	5
number of artefacts with retouch/usewear that are backed	0	0	0	0
total number of cores	0	0	0	0
% of artefacts with retouch/usewear	4.6	1.1	0.0	21.7
χ^2	9.423	33.141	na	na
$p(H_0)$	0.002	8.57×10^{-9}	na	na
reject H_0?	yes - increase	yes - decrease	na	na

To determine the effect of the presence of raw materials other than chert, chalcedony and silcrete after 9000 BP I recalculated the unit two proportions excluding them because these raw materials have less predicable flaking characteristics and are therefore less suitable for retouch. The removal of other raw materials from unit two results in a non-significant ($\chi^2 = 0.317$, df = 1, $p(H_0) = 0.573$) change in the percentage of worked artefacts from 2.2% (n = 20) to 2.6% (n = 17). Excluding quartz, bif and ironstone, from the analysis of worked artefacts because of their less predicable flaking characteristics *makes no difference* to the proportions of worked artefacts in unit two. This suggests that raw material preferences (of more predictable over less predictable) cannot explain the low proportion of worked artefacts within stratigraphic unit two.

The comparatively high proportions of worked artefacts in stratigraphic unit one is related to the overall abundance of chert artefacts (32.4%, n = 71) and in stratigraphic unit four is related to the overall abundance of silcrete artefacts (31.6%, n= 18). I considered that although the technological analysis indicated that there were no changes in rationing suggesting of changes in raw material availability, the size of raw material nodules may be relevant variable in the patterns of curation. In stratigraphic unit four silcrete is the most abundant raw material and the mean flake length of 27.2 mm (table 4.13) suggests that it was available in nodules that were large enough to produced flakes that could be retouched. In stratigraphic unit one the most abundant raw materials are chalcedony (35.2%, n = 77) and chert (32.4%, n = 71), but the mean flake length of all chert flakes is 13.3 mm (14.2 mm for retouched flakes) compared to the mean flake length of all chalcedony flakes of 8.51 mm (10.4 mm for retouched flakes). The differences in mean flake length, although not statistically significant (for lengths of retouched chert and chalcedony flakes, $t = 0.780$, $df = 8$, $p(H_0) = 0.457$), suggest that chert nodules for artefact production were larger than chalcedony nodules, allowing manufacture of relatively large chert flakes that were more suitable for retouching.

To summarise, changes in the proportions of worked artefacts at Marillana A probably relate to changes in the abundance of raw material types (which appears to be related to choice – that is, isoschrestic variation – more than availability) and the sizes of raw material nodules used for flake manufacture. There are only three cores at Marillana A and they all occur in stratigraphic unit two, probably because this unit has the highest number of artefacts and rarer items are more likely to be represented in larger samples. The implications of the appearance of backed artefact technology are difficult to evaluate because there are only two backed artefacts in the assemblage at Marillana A. That said, there are no significant changes in the technology of stone artefact production or site use that are concomitant with the appearance of backed artefacts at Marillana A. This suggests that the appearance of backed artefact technology was *not* associated with important economic changes at Marillana A. The increased preference for chert may be related to the appearance of the two chert backed artefacts but the small sample makes this difficult to demonstrate with certainty.

Total phosphorus, nitrogen and carbon concentrations in sediments at Marillana A

The small number of artefacts and the high proportion of worked silcrete artefacts discarded before 13,000 BP suggest that there may be some difference in the way the site was used between before 13,000 BP and after 9000 BP. So far, my analysis of soil and sedimentary organic materials indicates that occupation was most intensive after 9000 BP. The analysis of stone artefact discard and technology described in the previous sections indicated that Marillana A was most intensively occupied between 3000-9000 BP. The relationship between proportions of worked artefacts and changes in raw materials discussed in the previous section means there was some ambiguity whether the function of the site and the duration and frequency of visits remained constant over time. The question remaining is: was the occupation of Marillana A before 13,000 BP at a similar intensity to after 9000 BP but of a form that discarded few artefacts with a high proportion of worked artefacts?

To answer this question I measured total phosphorus, nitrogen and carbon concentrations (P, C, and N) in the sediments of selected spits to measure changes in the intensity of site use. Phosphorus, carbon and nitrogen concentrations are related to the discard of organic material and are independent of artefact variables such as discard, raw material and technology. Phosphorus indicates past concentrations of organic material because it is tightly bonded to the soil unlike other components of organic material such as carbon and nitrogen that are transformed to mobile gaseous or soluble compounds such as carbon dioxide, ammonium nitrate and nitrogen gas.

Phosphorus analysis has not been previously attempted at stratified sites in Australia and there are no reports of phosphorus analysis at stratified sites in arid/semi-arid regions elsewhere, as far as I am aware. I chose to sample excavation units from each stratigraphic unit (table 4.21) rather than every excavation unit because of the uncertainty involved in obtaining useful results at Marillana A and the expense and time involved in the process. To standardise the different depths, masses and proportions of particle sizes of sediment in each excavation unit, I transformed concentrations of P, C and N measured in the analysed sample to a mass of P per cubic metre of $<-1\phi$ fraction of sediment. Table 4.21 shows the masses of P, C and N per cubic metre of $<-1\phi$

fraction per excavation unit, the number of stone artefacts per cubic metre per excavation unit, sediment pH and soluble salt content. The step-like reductions in P, C and N suggest that gradual processes such as erosion, leaching and decomposition have not substantially influenced the distribution of P, C and N in the sequence.

Table 4.21 Summary of sediment chemical data from Marillana A square 9B

SU = stratigraphic unit
EU = excavation unit

years BP	SU	EU	total P as $\%P_2O_5$ in analysed sample	total P (g) per m^3 sand fraction	total C as %C in analysed sample	total C (g) per m^3 sand fraction	total N as %N in analysed sample	total N (g) per m^3 sand fraction	soluble salt mS cm^{-1}	pH	artefacts m^{-3}
0-3000	1	3	0.143	1029.08	2.588	18549.46	0.302	2164.58	9.37	7.33	3786
3000-9000	2	11	0.185	1137.57	2.531	18713.91	0.237	1752.35	6.8	7.39	4433
	2	17	0.147	704.34	1.763	11791.08	0.054	361.16	0.49	8.04	1500
9000-13,000	3	21	0.185	2003.16	0.742	4690.69	0.060	379.30	3.36	7.15	833
	3	24	0.051	170.06	0.360	647.83	0.126	226.74	8.41	6.95	0
	3	26	0.068	288.62	0.452	1298.38	0.063	180.97	4.89	7.31	0
>13,000	4	29	0.078	597.72	0.353	2076.45	0.030	176.47	1.83	7.95	133
	4	32	0.080	883.35	0.212	1280.91	0.041	247.72	2.97	7.31	0
	4	36	0.063	300.16	0.268	1559.59	0.030	174.58	1.79	7.99	167
	4	38	0.080	201.60	0.450	3312.88	0.044	323.93	2.05	7.71	67

The masses of P, C and N are shown in figures 4.36-4.38, where excavation unit 21 stands out with an unusually high concentration of P. This outlier may result from the concentration of P at the roof fall interface between unit two and unit three because of reduced rates of sedimentation. Table 4.22 shows the Pearson product-moment correlation coefficient statistic calculated for all relationships between the variables after excavation unit 21 is removed. Table 4.22 shows strong positive correlations between P, C, N concentrations and artefact density. A moderate correlation exists between soluble salt concentration and artefact density suggesting there is some relationship, but a strong positive relationship between soluble salt concentration and pH indicates that soluble salt concentration is probably sensitive to non-cultural as well as cultural variables. Very weak correlations between pH and P, C and N indicate that preservation conditions have not significantly influenced the retention of these elements in the sediments.

Figure 4.36 Concentration of phosphorus in sediment samples from Marillana A square 9B. Total phosphorous concentration expressed as $\%P_2O_5$.

SU = stratigraphic unit

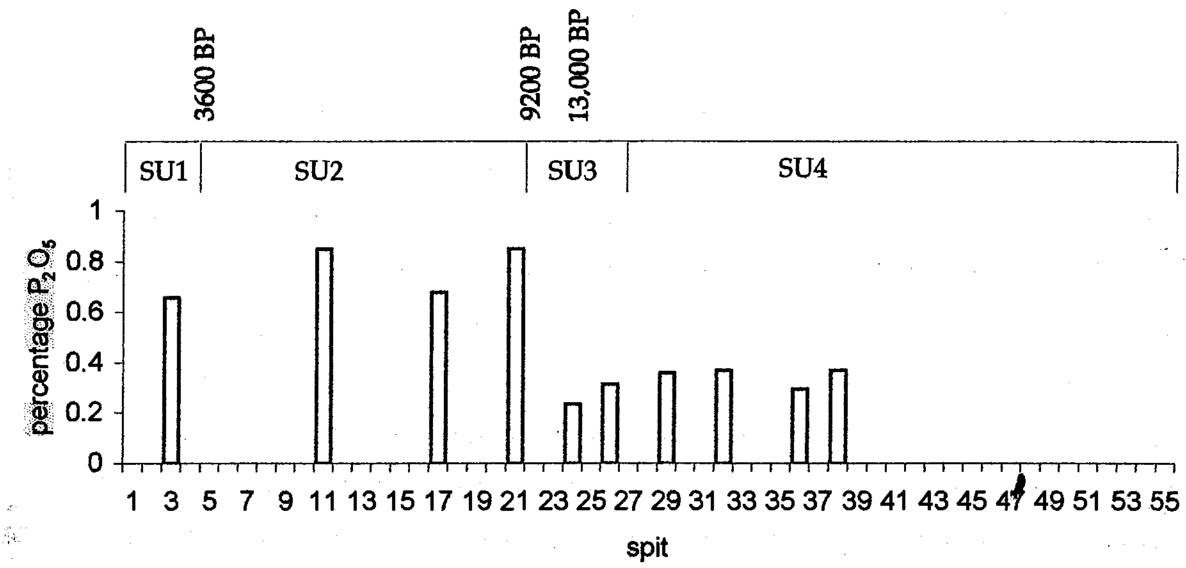


Figure 4.37 Concentration of total carbon in sediment samples from Marillana A square 9B

SU = stratigraphic unit

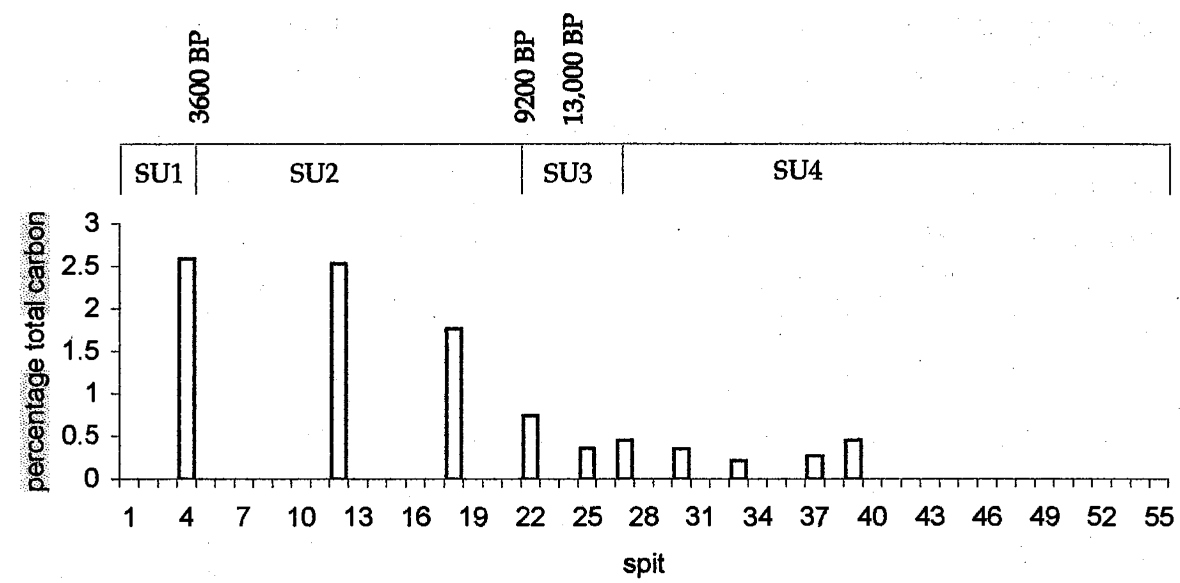


Figure 4.38 Concentration of total nitrogen in sediment samples from Marillana A square 9B

SU = stratigraphic unit

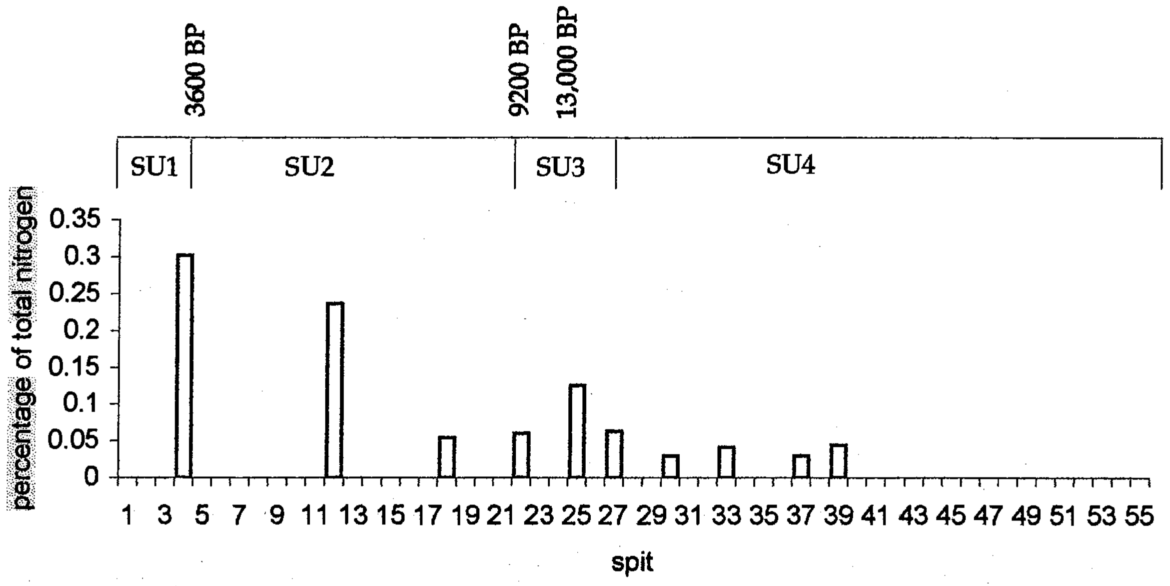


Table 4.22 Correlations between chemical and cultural variables at Marillana A square 9B.

Spit 21 excluded for calculation of Pearson's product-moment correlation coefficient
Bold type indicates $p(H_0) < 0.05$

	C	N	pH	soluble salts	artefacts
P	**0.785**	**0.783**	0.053	0.257	**0.800**
C		**0.913**	0.019	0.416	**0.976**
N			0.272	0.665	**0.949**
pH				**0.825**	0.130
soluble salts					0.522

To summarise the P, C and N analysis, the approach is useful for determining intensity of occupation when considered with other chemical and cultural variables. The P, C and N evidence for Marillana A shows an increase in organic material discard after 9000 BP indicating that there is a significant increase in occupation intensity after 9000 BP. This result, in conjunction with the results of the stone artefact analysis, suggests that there are qualitative and quantitative differences in the way Marillana A was used before 13,000 BP and after 9000 BP.

Magnetic susceptibility of sediments at Marillana A

Although the P, C and N evidence indicates that occupation intensity increased after 9000 BP, like the worked artefact evidence, it does not indicate whether the increased intensity consisted of longer stays at the site or more frequent brief visits. To discern between longer visits and shorter visits at Marillana A I analysed the magnetic susceptibility of the sediments. I expected long stays to be indicated by high magnetic susceptibility as sediments are repeatedly fired in the same area. Brief visits should be indicated by low magnetic susceptibility because sediments are not frequently fired and not frequently fired in the same place.

Figure 4.39 shows that a change in magnetic susceptibility occurs at excavation units 19-24 in stratigraphic unit three, but there is little difference in the magnetic susceptibility of sediments before 13,000 BP and after 9000 BP. X-ray fluorescence evidence indicates that the iron (the main contributor to the magnetic properties of the sediment) content of the sediments does not change at 9000-13,000 BP indicating no changes in the iron mineralogy that might result in a decline in magnetic susceptibility (figure 4.40). X-ray fluorescence evidence shows peaks in calcium and sulphur, indicating a high concentration of gypsum at 9000-13,000 BP (cf. figures 4.16-4.17). The addition of diamagnetic materials such as gypsum (Heiland 1940) dilutes magnetic minerals, altering susceptibility as seen in figure 4.39, but having little effect on ratios between magnetic parameters such as the coefficient of frequency dependency (figure 4.41, Gale and Hoare 1991:211). The coefficient of frequency dependency (figure 4.41) shows a slight increase after 9000 BP, but this is not significant ($\chi^2 = 0.160$, df = 18, $p(H_0) = 0.689$).

Figure 4.39 Magnetic susceptibility of sediment samples from Marillana A square 9B

SU = stratigraphic unit

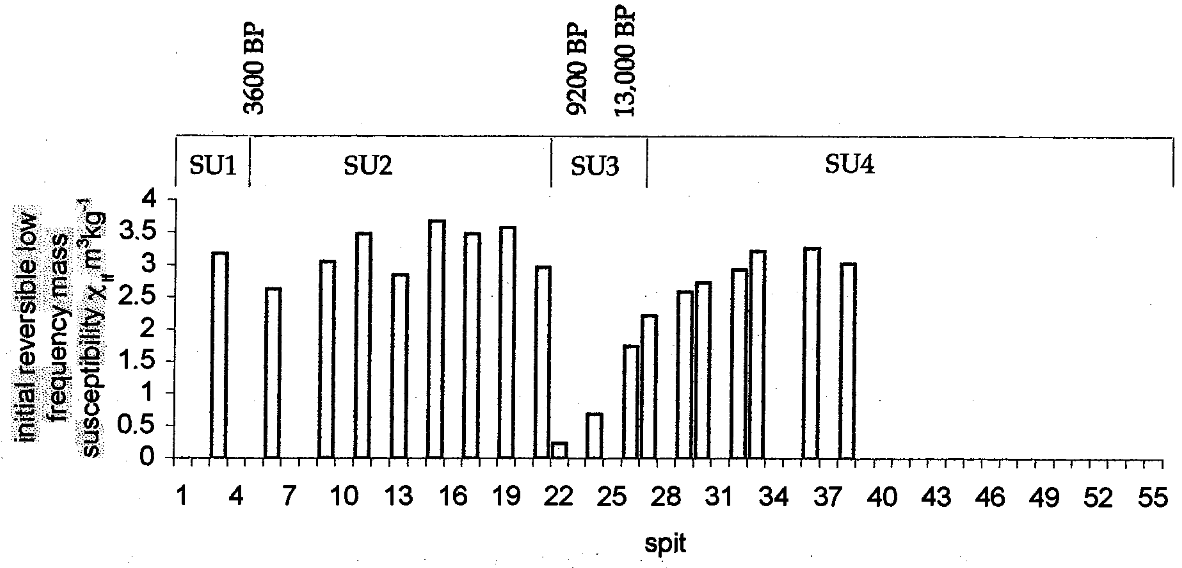


Figure 4.40 Concentration of iron in sediment samples from Marillana A square 9B. Total iron expressed as %Fe_2O_3.

SU= stratigraphic unit

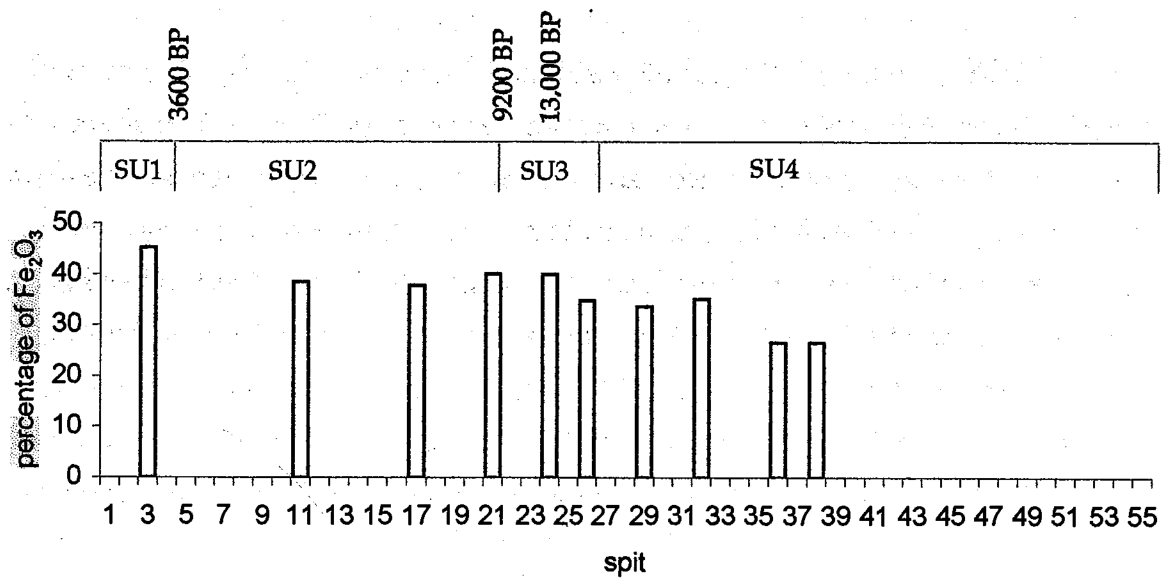
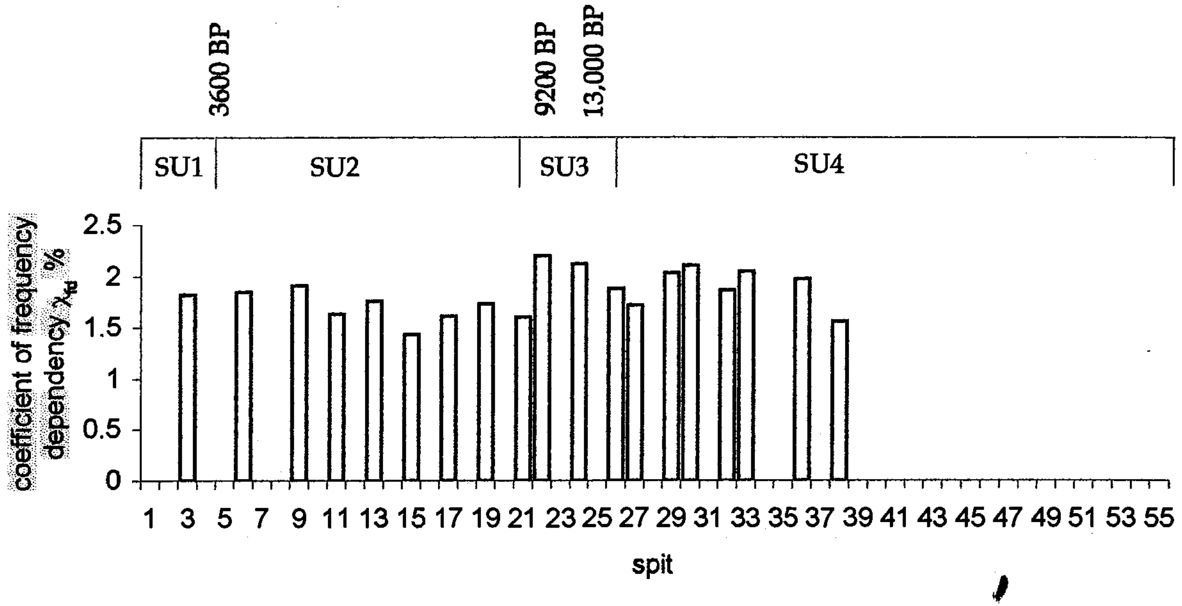


Figure 4.41 Coefficient of frequency dependency for sediment samples from Marillana A square 9B

SU = stratigraphic unit



The absence of a relationship between magnetic susceptibility and other variables is shown in the correlation coefficients in table 4.23. The weak correlation between magnetic susceptibility and soluble salts may reflect the low solubility of gypsum in water (Courty *et al.* 1989:171). The weak correlation between magnetic susceptibility and artefact density suggests that magnetic susceptibility was not influenced by changes in the intensity of occupation. The moderate positive correlation of frequency dependency with charcoal density confirms that the magnetic susceptibility of the sample analysed here is sensitive to the intensity of human or natural firing at Cleft Rock Shelter. However the poor match between the distribution of charcoal (figures 4.11 and 4.12) and frequency dependency (figure 4.41) suggests that this relationship is of limited relevance.

Table 4.23 Correlations between magnetic, cultural and other variables at Marillana A square 9B

χ_{lf}= **initial reversible low frequency mass susceptibility**
χ_{fd}= **coefficient of frequency dependency**
Bold type indicates $p(H_0) < 0.05$

	artefacts	soluble salts	charcoal	soil organic material
χ_{lf}	0.351	0.282	0.382	0.174
χ_{fd}	0.311	0.067	0.535	0.321

To summarise the magnetic susceptibility evidence, it indicates that the intensity of firing probably did not change throughout the history of occupation of Marillana A. This may indicate that the occupation of Marillana A was always in the form of brief visits, but the influence of changes in sediment mineralogy on magnetic susceptibility at 9000-13,000 BP suggests that magnetic susceptibility is influenced by non-cultural variables as well as changes in human firing patterns.

Discussion

Before 13,000 BP, Marillana A was visited briefly and infrequently and silcrete was the preferred raw material for artefacts. Between 13,000 BP and 9000 BP a roof fall event occurred and human occupation reduced or ceased. Stone artefacts and organic material, such as charcoal and faunal remains, and P, C and N concentrations indicate that Marillana A was most intensively occupied during the period 9000 BP to 3000 BP. At that time silcrete is replaced by chert and chalcedony as the preferred raw materials for artefacts, but there are no changes in artefact manufacturing technology from before 9000 to after 3000 BP. Stone artefact evidence and magnetic susceptibility evidence suggest that the function of Marillana A as a site of brief visits appears not to have changed throughout the history of its occupation, although the P, C and N concentrations suggest that the frequency of these visits increased significantly after 9000 BP. New types of stone technology are represented by backed artefacts at 9000-3000 BP (excavation units thirteen and four) and adzes at 3000-0 BP (surface). Aside from the appearance of these new artefacts, there are no changes in artefact technology in the late Holocene. The small number of the new technological types (two backed artefacts in stratified contexts) means that they cannot be associated with the other changes at the site with any confidence.

5. Results and analysis: Marillana B

Marillana B is a north-facing rockshelter in Marra Mamba ironstone formation to the north of Marillana Creek, near the confluence of Marillana and Iowa Creeks. It is a shallow overhang (3.7 m deep by 3.5 m high at the drip line) located behind a thicket of small fig trees that are growing closely against the rock face (figure 5.1, Strawbridge 1992:15). The height of the shelter tapers to less than a metre at 1.6 m from the drip line, suggesting that human activity was concentrated near the drip line (figure 5.1). The surface of the rockshelter was covered with leaves, charcoal, scats and 20.5 kg of roof-fall pieces. A small grinding fragment (15 x 16 cm) was recorded on the surface of the centre of the shelter.

Excavation

Lynda Strawbridge and her assistants excavated the shelter in November 1993. A one by one metre square (labelled 4A) located just inside the centre of the drip line was excavated in 30 excavation units of about 2 to 3 cm each to a depth of 79 cm (figure 5.2).

The timing of occupation

To identify the time represented by the archaeological record at Marillana B, I used a radiocarbon date, Strawbridge's field descriptions and my analysis of sediment particle size and colour (figures 5.2-5.3). Strawbridge's section drawing shows a change in stratigraphy at about 32 cm below surface in the east half of the square (figure 5.2). I submitted a sample from charcoal collected in sieves from the interface of the two layers (excavation unit 13, 32 cm below surface) that returned a date of 1791±57 BP (Wk 10350). In the absence of any charcoal below excavation unit 13, a soil sample from excavation unit 27 was submitted to the University of Waikato Radiocarbon Dating Laboratory. The soil sample was found to insufficient amounts of carbon for accurate dating.

Figure 5.1 Section and plan of Marillana B rockshelter. Redrawn from Strawbridge's field drawings and measurements.

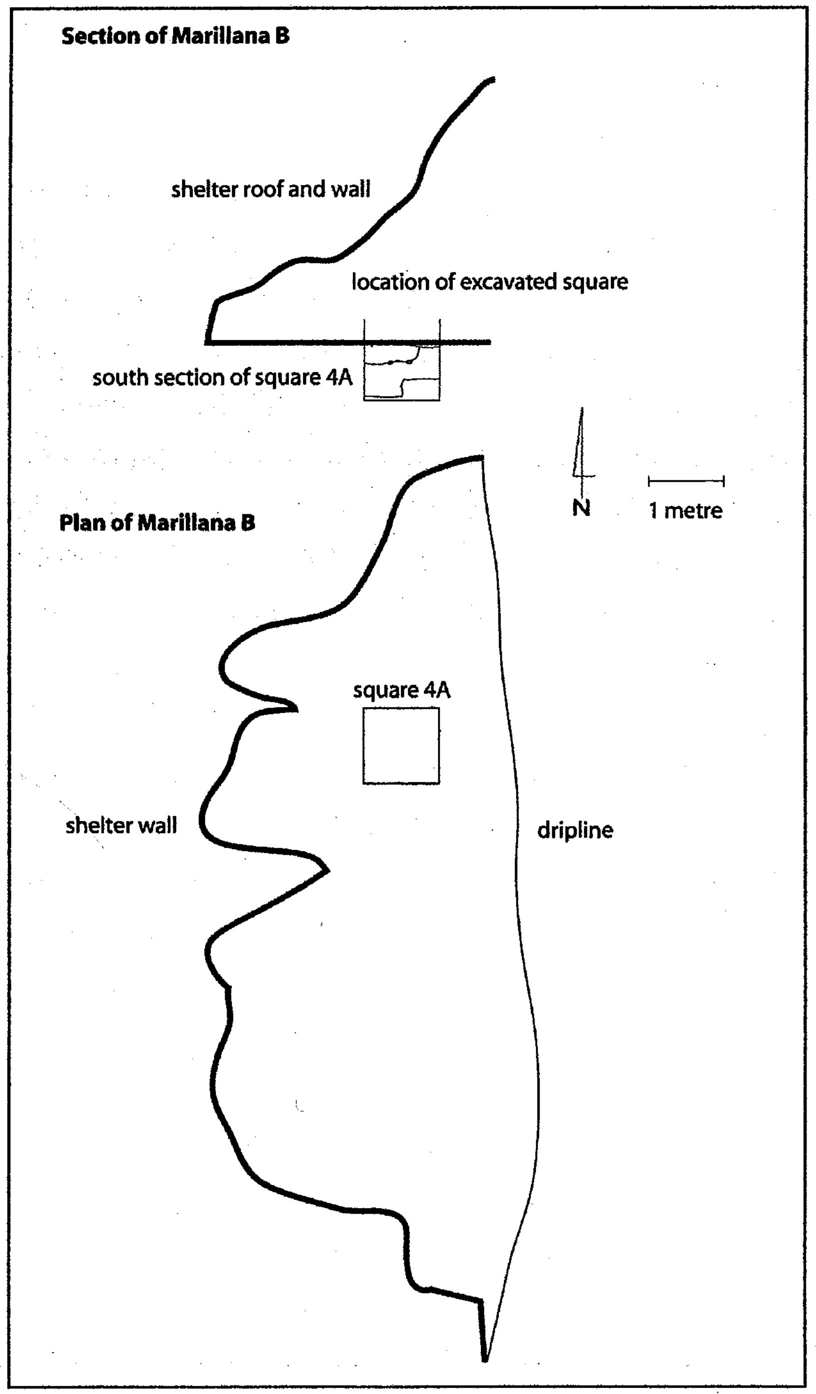


Figure 5.2 South section of excavated square 4A at Marillana B. Redrawn from Strawbridge's field drawings.

SU= stratigraphic unit
EU = excavation unit
lab= analysis undertaken under laboratory conditions during 2001-2

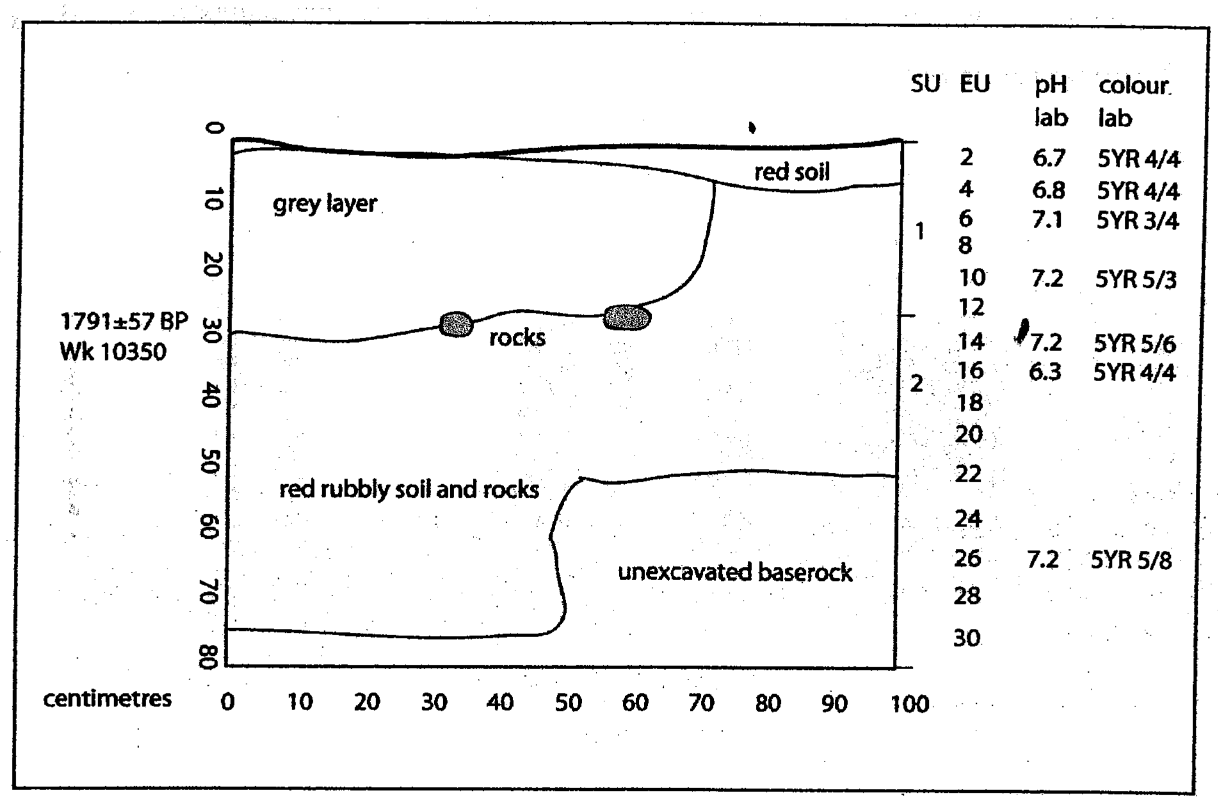


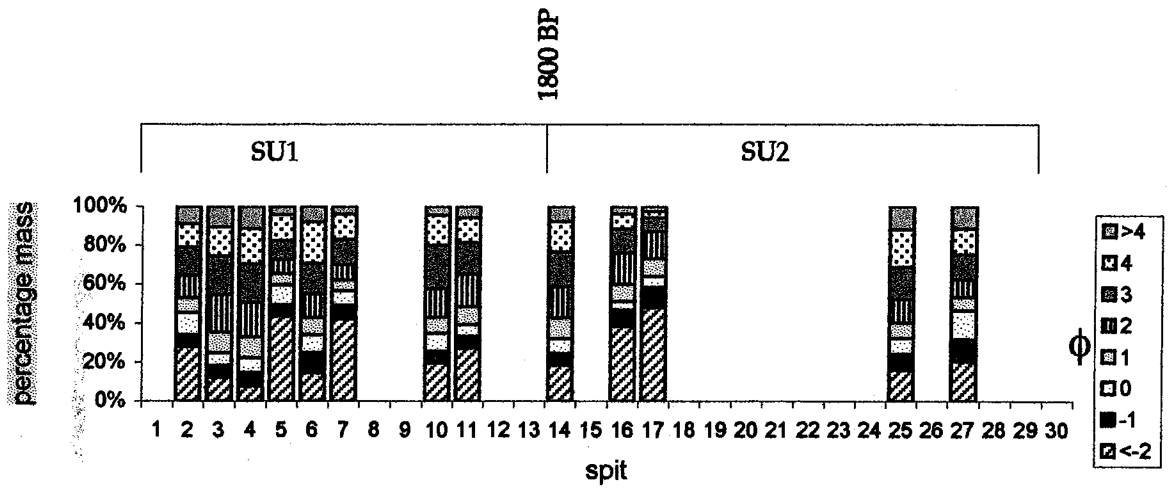
Figure 5.3 shows the distribution of particle sizes in the sediment samples available for analysis. The differences in the distributions of particle sizes and other sediment data and the gaps in the samples suggest that the excavation units cannot be convincingly divided into stratigraphic units reflecting the stratigraphic divisions in Strawbridge's section drawing. A more complete sample may identify excavation units that can be grouped together on similar sedimentary attributes. It is also possible that once sediment samples were taken from their stratified contexts the differences that Strawbridge observed and recorded in her section drawing may have disappeared, become less pronounced or were unidentifiable using the techniques I employed.

I divided the deposit into two stratigraphic units at excavation unit 13 (32 cm below surface) because of the stratigraphic divisions recorded by Strawbridge.

Unit one consists of the surface layer to excavation unit 13 (0-32 cm below surface) and spans recent times to about 1800 BP. Unit two includes excavation units 14-30 (32-79 cm below surface) and dates to after 1800 BP. As explained above, no dates are available for the base of unit two because of the small amount of charcoal.

Figure 5.3 Particle size distribution at Marillana B. Particle size fractions expressed as phi.

SU = stratigraphic unit



CHANGES IN THE INTENSITY AND TYPE OF OCCUPATION

Organic material and soluble salt concentration

I analysed the distribution of soil organic material and charcoal as possible indicators of changes intensity of human occupation at Marillana B. Figure 5.4 shows the distribution of soil organic material as a gradual decay with increasing depth. The peak in excavation unit 15 may be anomalous as it does not coincide with peaks in other variables or a stratigraphic change. There was no sedimentary organic material available from Marillana B for analysis.

Figure 5.4 Soil organic material distribution at Marillana B

SU = stratigraphic unit

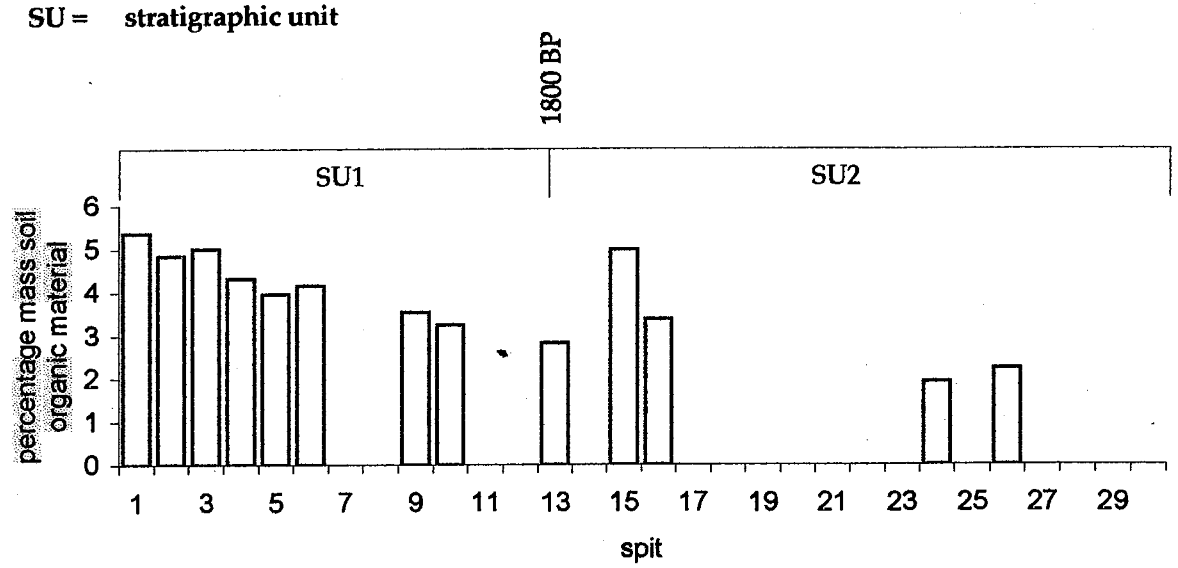


Figure 5.5 shows the distribution of charcoal throughout the sequence at Marillana B. The highest density of charcoal occurs in the middle of unit one, confirming Strawbridge's description of stratigraphic unit one as a 'grey ashy layer'. Figure 5.6 shows that the concentration of soluble salts is similar to the charcoal distribution with a peak in stratigraphic unit one and very low levels in unit two. The small concentrations of charcoal and soluble salts in stratigraphic unit two may be a result of different site formation conditions between stratigraphic unit one and two rather than the absence of human fire-making activity.

Figure 5.5 Charcoal density at Marillana B

SU = stratigraphic unit

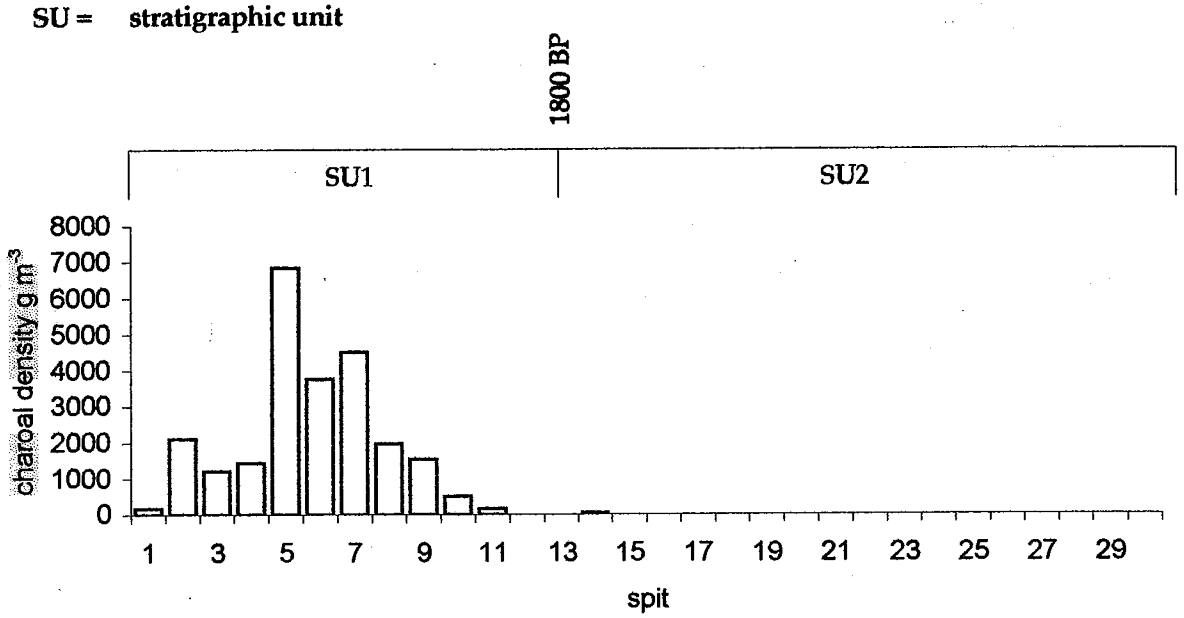


Figure 5.6 Soluble salt concentration at Marillana B

SU = stratigraphic unit

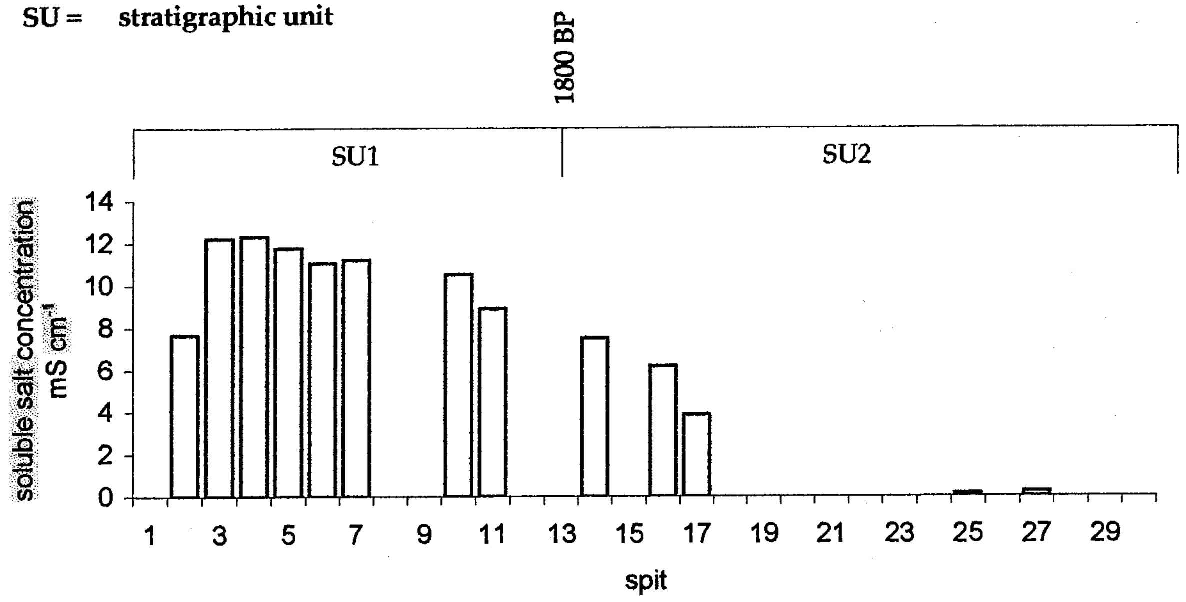
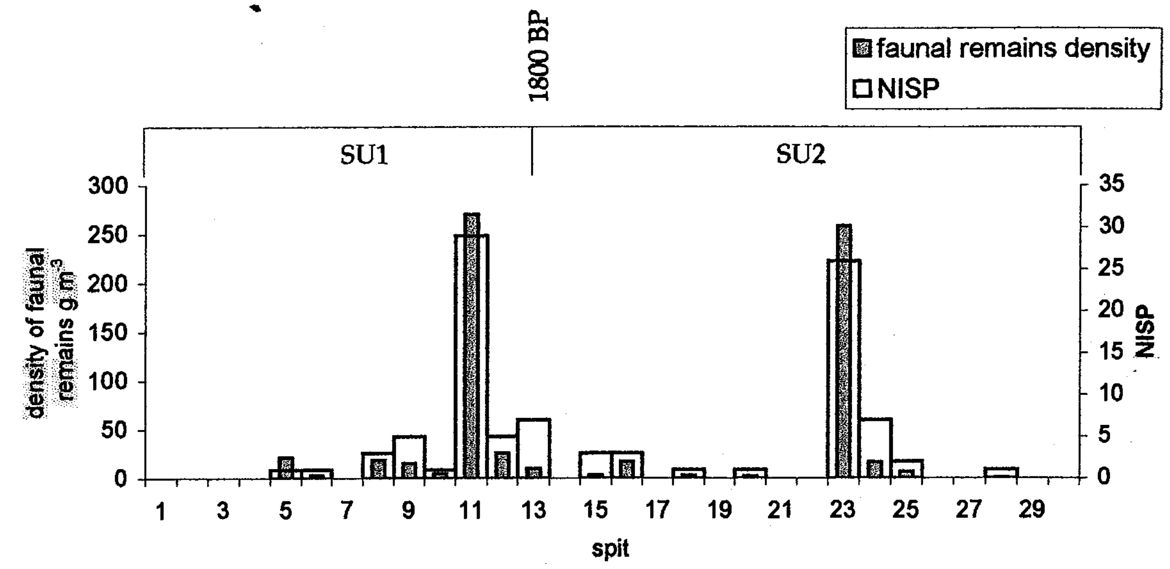


Figure 5.7 shows the distribution of faunal material at Marillana B with peaks in stratigraphic unit one and two. The total mass of the 109 specimens of faunal remains at Marillana B is 18.14 g (13.13 g in stratigraphic unit one, 5.01 g in stratigraphic unit two), the mean mass is 0.16 g and the range is 0.98 g to 0.01 g. The mass/NISP ratio decreases with depth below surface at Marillana B suggesting that exposure to weathering and site formation processes contribute to bone fragmentation. The highly fragmented assemblage and small size of specimens made identification difficult but I was able to identify eight specimens (2.39 g in total, 1.22 g in stratigraphic unit one, 1.17 g in stratigraphic unit two) as molar fragments of *Macropus* sp. Thirteen specimens (5.78 g in total, 5.76 g in stratigraphic unit one, 0.02 g in stratigraphic unit two) were identified as long bone shaft fragments, probably of small mammals. Twelve burnt specimens were identified, all unidentified fragments and nine of them in excavation unit 11 (stratigraphic unit one). The presence of burnt bone fragments suggests that humans may have contributed to the formation of the faunal assemblage by burning bone. None of the *Macropus* sp. molar fragments were burnt suggesting that the presence of these specimens is unrelated to human subsistence activity and may have accumulated through the activities mammalian carnivores similar to Marillana A.

Figure 5.7 Faunal material density and NISP at Marillana B

SU = stratigraphic unit



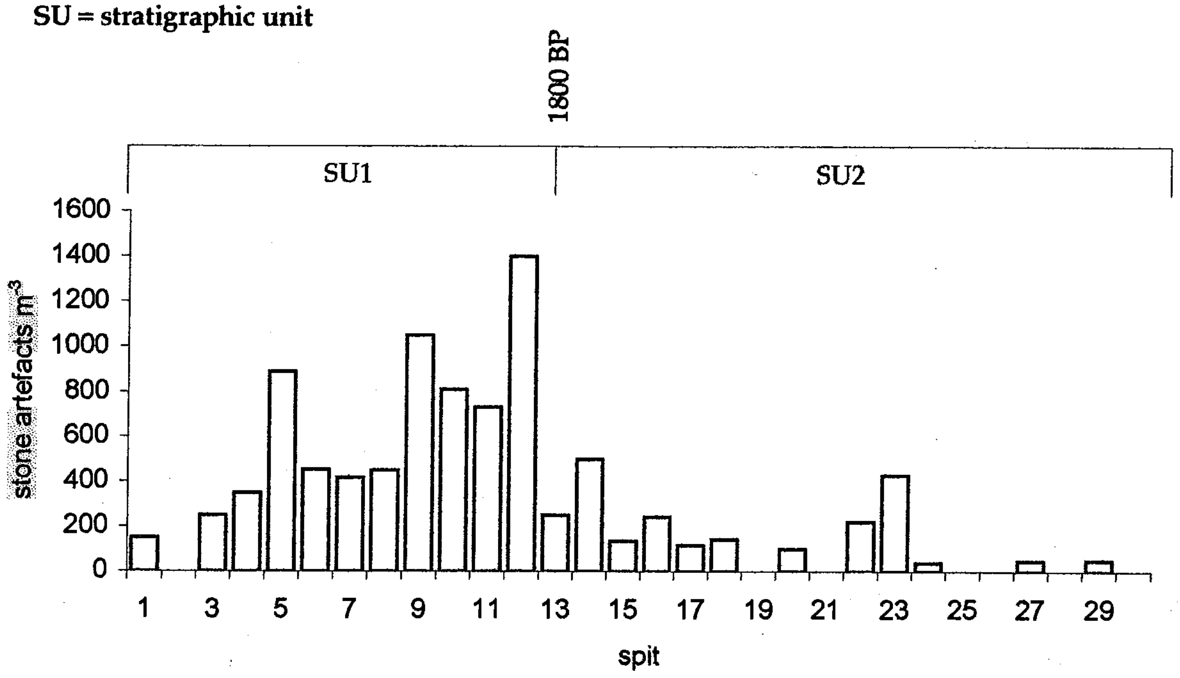
To summarise the organic and soluble salt evidence, the highest densities of soil organic material, faunal remains, charcoal and soluble salts occur in stratigraphic unit one. This suggests that human occupation may have been most intensive at Marillana B after 1800 BP. On the other hand, the sparse record of sedimentary information, particularly after excavation unit 17, means that it is not possible to exclude changes in site formation processes as the cause of the difference densities of organic materials and soluble salts.

Stone artefacts

I measured changes in the intensity of occupation using the stone artefact assemblage. Stone artefacts from Marillana B may provide a more accurate record of human occupation than organic material and soluble salts because they are less sensitive to decay during exposure or changes in site formation processes. In addition, there is a more complete record of stone artefacts than organic remains from Marillana B. Figure 5.8 shows the density of stone artefacts for each spit at Marillana B. The peak of artefact discard occurs after 1800 BP and declines in the upper layers.

Figure 5.8 Stone artefact discard at Marillana B (n = 226)

SU = stratigraphic unit



Post-depositional change

To determine whether post-depositional processes such as trampling can explain the peak in artefact discard after 1800 BP, the degree of breakage in each unit was measured using the Sullivan and Rozen (1985) typology. Table 5.1 shows the number of each debitage type in the two units. The difference in the numbers of each type between the two units is not significant ($\chi^2 = 1.540$, df = 3, $p(H_0) = 0.627$). The absence of a significant difference in debitage types between the two stratigraphic units suggests that post-depositional processes were not responsible for the peak in artefact discard in unit one. No conjoins were identified at Marillana B.

Table 5.1 Debitage analysis of stone artefacts from Marillana B

SU = stratigraphic unit
n = number of artefacts
$\%_1$ = percent of total artefacts recovered from the site
$\%_2$ = percent of total artefacts recovered from stratigraphic unit

SU	total artefacts		complete flake		broken flake (long)		broken flake (trans)		flake fragment		angular piece	
	n	$\%_1$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$
1	178	78.8	43	24.2	3	1.7	1	0.6	48	27.0	81	45.5
2	48	21.2	14	29.2	0	0.0	0	0.0	12	25.0	21	43.8

Artefact manufacture

Raw materials

To determine the influence of changes in raw materials on the change in artefact discard changes in the number of artefacts representing each raw material were analysed. Table 5.2 shows the number of stone artefact for each raw material found in the two stratigraphic units at Marillana B. Chert and chalcedony are the most frequently represented raw materials at Marillana B.

Table 5.2 Raw material of stone artefacts at Marillana B

SU= stratigraphic unit
n= number of artefacts
$\%_1$ = percent of total artefacts recovered from the site
$\%_2$ = percent of total artefacts recovered from stratigraphic unit

SU	total artefacts		chert		siltstone		ironstone		quartz		chalcedony		silcrete		others	
	n	$\%_1$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$
1	178	78.8	66	37.1	11	6.2	8	4.5	16	9.0	63	35.4	9	5.1	5	2.8
2	48	21.2	23	47.9	5	10.4	0	0.0	7	14.6	10	20.8	0	0.0	3	6.3

Differences in the number of chert artefacts between stratigraphic unit one and two are not significant ($\chi^2 = 1.860$, df = 2, $p(H_0) = 0.172$). Similarly, differences in the number of chalcedony artefacts between stratigraphic unit one and unit two are not significant ($\chi^2 = 3.664$, df = 2, $p(H_0) = 0.055$). The absence of differences in the raw materials of stone artefacts suggests that changes in raw materials do not explain the changes in artefact density.

Technological variables

To see whether changes in raw material conservation strategies could explain the change in artefact discard rate I looked for changes in technological and metric variables between the two units. Tables 5.3 – 5.4 show that there are no significant changes in the manufacturing techniques of complete flakes made from chert and other raw materials. There is an increase in the number of chert flakes with overhang removal, but as this is not associated with other indicators of increased efficiency, such as reduced dorsal cortex and increased cortical platforms, it is unlikely to indicate a substantial change in artefact manufacturing technique.

Table 5.3 Summary of technological analysis of chert flakes from Marillana B

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit 1		2					
	years BP	0-1800		>1800					
	number of chert complete flakes	29		7					
	% of all flakes in the unit that are chert	67.4		50					
						significant change in variable?			
		n	%	n	%	Reject H_0?	C_{adj}	when?	direction?
termination	feather	22	75.9	6	85.7	no	na	na	na
platform surface	flat	17	58.6	5	71.4	no	na	na	na
	facetted	6	20.7	1	14.3	no	na	na	na
	cortical	5	17.2	1	14.3	no	na	na	na
platform type	wide	23	79.3	6	85.7	no	na	na	na
	focalised	2	6.9	1	14.3	no	na	na	na
	gull	3	10.3	0	0.0	no	na	na	na
overhang removal	flakes with overhang removal	12	41.4	0	0.0	no	na	na	na
reduction level	flakes with >1 dorsal flake scar	12	41.4	3	42.9	no	na	na	na
	flakes with distal and lateral flake scars	0	0.0	0	0.0	no	na	na	na
	flakes with <10 cortex	18	62.1	2	28.6	no	na	na	na
	flakes with 10-50 cortex	7	24.1	4	57.1	no	na	na	na
	flakes with >50 cortex	3	10.3	1	14.3	no	na	na	na

Table 5.4 Summary of technological analysis of flakes made from raw materials other than chert from Marillana B

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit 1		2					
	years BP	0-1800		>1800					
	number of other complete flakes	14		7					
	% of all flakes that are not chert	32.6		50					
						significant change in variable?			
		n	%	n	%	reject Ho?	C_{ad}	when?	direction?
termination	feather	13	92.9	6	85.7	no	na	na	na
platform surface	flat	5	35.7	4	57.1	no	na	na	na
	facetted	3	21.4	1	14.3	no	na	na	na
	cortical	6	42.9	2	28.6	no	na	na	na
platform type	wide	11	78.6	6	85.7	no	na	na	na
	focalised	1	7.1	1	14.3	no	na	na	na
	gull	2	14.3	0	0.0	no	na	na	na
overhang removal	flakes with overhang removal	4	28.6	2	28.6	no	na	na	na
reduction level	flakes with >1 dorsal flake scar	3	21.4	2	28.6	no	na	na	na
	flakes with distal and lateral flake scars	0	0.0	0	0.0	no	na	na	na
	flakes with <10 cortex	5	35.7	2	28.6	no	na	na	na
	flakes with 10-50 cortex	3	21.4	3	42.9	no	na	na	na
	flakes with >50 cortex	5	35.7	2	28.6	no	na	na	na

Table 5.5 shows that chert artefacts significantly decrease in size after 1800 BP (figures 5.9-5.10). Table 5.6 shows that artefacts made from other raw materials also reduce in size after 1800 BP, but not by a significant amount (figures 5.11-5.12). The reduction in chert artefact size *possibly* indicates increased efficiency in artefact manufacture, but the absence of *substantial and significant* changes in technological variables suggests that efficiency does not convincingly explain the reduction in chert flake sizes after 1800 BP. It should be noted that the reduction in size of chert flakes after 1800 BP is also accompanied by a change in the shape of the flakes from short and wide to longer and thinner flakes. This may reflect a trend towards the production of more blade-like flakes in preparation for backing, but only two flakes in the entire assemblage are blades

(having a length-width ratio greater than or equal to two). The small number of blade-like flakes at Marillana B suggests that blade production does not convincingly explain the change in shape and size of chert flakes after 1800 BP.

Table 5.5 Summary of metric analysis of chert flakes from Marillana B

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t- tests

	stratigraphic unit	1	2
	time period	0-1800	>1800
	total number of chert artefacts	66	23
	total number of chert flakes	29	7
mass of total artefacts	mean (g)	1.6	3.5
significant change?	t	-2.135	na
	$p(H_0)$	0.036	na
	reject H_0?	yes - decrease	na
flake length	mean (mm)	15.0	19.8
significant change?	t	-1.254	na
	$p(H_0)$	0.218	na
	reject H_0?	no	na
flake width	mean (mm)	13.6	25.1
significant change?	t	-2.604	na
	$p(H_0)$	0.014	na
	reject H_0?	yes - decrease	na
flake thickness	mean (mm)	3.5	5.2
significant change?	t	-1.783	na
	$p(H_0)$	0.083	na
	reject H_0?	no	na
flake mass	mean (g)	2.1	5.9
significant change?	t	-2.164	na
	$p(H_0)$	0.038	na
	reject H_0?	yes - decrease	na
flake platform width	mean (mm)	9.3	14.3
significant change?	t	-2.057	na
	$p(H_0)$	0.047	na
	reject H_0?	yes - decrease	na
flake platform thickness	mean (mm)	2.7	3.7
significant change?	t	-1.491	na
	$p(H_0)$	0.145	na
	reject H_0?	no	na

Table 5.6 Summary of metric analysis of flakes made from raw materials other than chert from Marillana B

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t- tests

	stratigraphic unit	1	2
	time period	0-1800	>1800
	total number of other artefacts	112	25
	total number of other flakes	14	7
mass of total artefacts	mean (g)	1.0	2.4
significant change?	t	-1.492	na
	$p(H_0)$	0.138	na
	reject H_0?	no	na
flake length	mean (mm)	13.2	18.2
significant change?	t	-1.434	na
	$p(H_0)$	0.168	na
	reject H_0?	no	na
flake width	mean (mm)	13.2	16.6
significant change?	t	-1.082	na
	$p(H_0)$	0.293	na
	reject H_0?	no	na
flake thickness	mean (mm)	3.7	3.9
significant change?	t	-0.518	na
	$p(H_0)$	0.611	na
	reject H_0?	no	na
flake mass	mean (g)	2.9	2.9
significant change?	t	-1.181	na
	$p(H_0)$	0.252	na
	reject H_0?	no	na
flake platform width	mean (mm)	8.9	10.6
significant change?	t	-0.329	na
	$p(H_0)$	0.746	na
	reject H_0?	no	na
flake platform thickness	mean (mm)	2.8	3.1
significant change?	t	-0.539	na
	$p(H_0)$	0.596	na
	reject H_0?	no	na

Figure 5.9 Frequency distribution of chert flake lengths in unit one of Marillana B

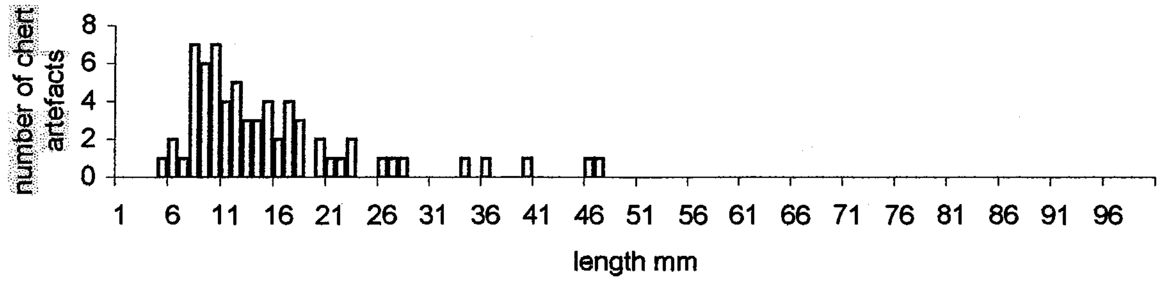


Figure 5.10 Frequency distribution of chert flake lengths in unit two of Marillana B

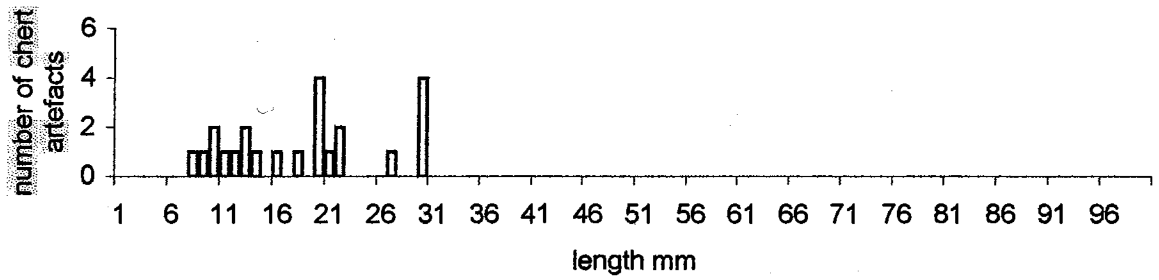


Figure 5.11 Frequency distribution of lengths of flakes made from raw materials other than chert in unit one of Marillana B

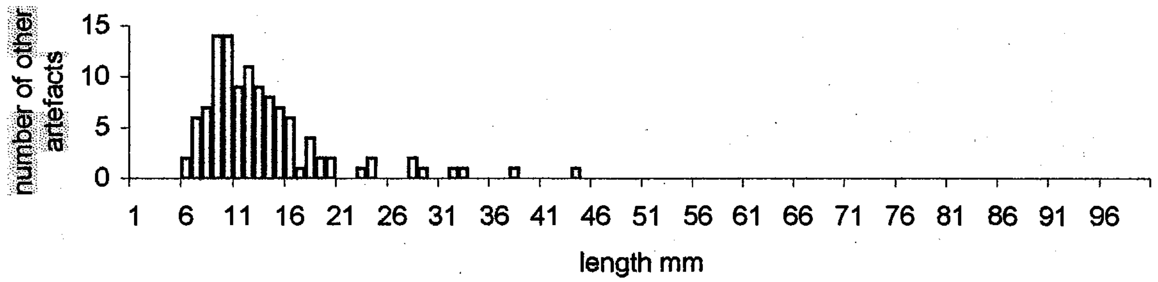
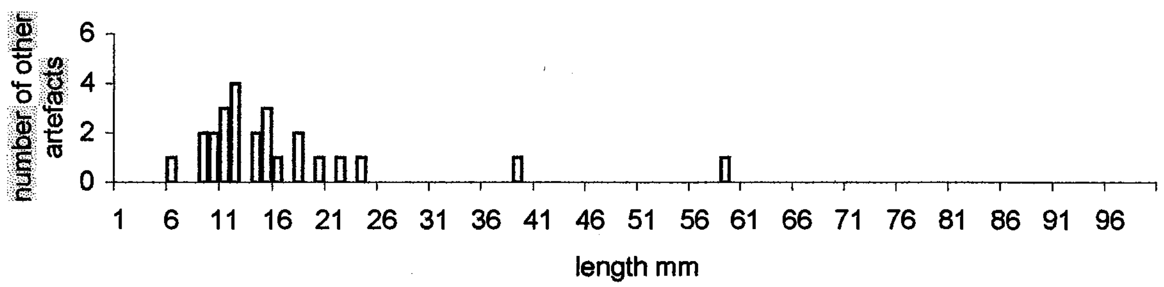


Figure 5.12 Frequency distribution of lengths of flakes made from raw materials other than chert in unit two of Marillana B



In summary, there are no changes in raw materials and artefact manufacturing technology that might explain an increase in discard after 1800 BP. Different raw materials appear to have been used similarly in flake production. At Marillana B there is no evidence of substantial changes in the efficiency of artefact manufacture or changes in the level of reduction that can be linked to changes in artefact discard.

Change in the function of the site

The only worked artefact recovered from Marillana B was a chert flake on the surface. One chert core was found in excavation unit 22 (stratigraphic unit two). The small size of the artefact assemblage and the absence of worked artefacts, including backed artefacts, throughout the excavated deposit suggests that Marillana B was a site of brief visits and relatively low intensity stone working throughout the history of its occupation.

Discussion

Marillana B was first occupied before 1800 BP. Evidence from stone artefacts, organic material and soluble salts suggest that occupation intensity at Marillana B peaked shortly after 1800 BP. The small numbers of cores and worked flakes throughout the occupation sequence suggest that there were no changes in the function of the site and indicate that it was a location for brief visits throughout the history of its occupation. This suggests that the peak in occupation intensity after 1800 BP probably resulted from an increase in the frequency of visits or increase in frequency of stone working per visit rather than increased duration of visits or change in the function of the site. The peak in occupation intensity is accompanied by decrease in the size of chert artefacts, but there are no substantial or significant technological changes suggestive of a change in the efficiency of artefact manufacture at 1800 BP. Although Marillana B has a relatively short and sparse sequence of occupation it is significant because it supports the pattern described in chapter two of increases in the number of sites and intensities of site occupation during the late Holocene.

6. Results and analysis: Cleft Rock Shelter

Cleft Rock Shelter is in the side of Fig Tree Gully, a wide gully that runs from the Hamersley Plateau through the rugged scarp of the Hamersley Ranges and onto the Fortescue River plain (figure 4.1). The shelter is 5 m above the gully floor and is 12.1 m wide and 3 m high at the drip line and 15 m deep (figure 6.1, Strawbridge 1988:10). The shelter is in an area of Brockman Formation ironstone, unlike the other three shelters, which are in Marra Mamba Formation ironstone (Thorne and Trendall 2001).

A surface scatter outside the shelter included three large basal grindstones, an adze slug and five flakes (some with signs of utilisation) (Strawbridge 1988:10). On the inside of the shelter were several fragments of grinding material, one intact upper grindstone and a piece of red ochre (Strawbridge 1988:10-11). These items were not available for inclusion in my analysis.

EXCAVATION

The shelter was excavated in 1990 and 1991 by Lynda Strawbridge and her assistants. Local Aboriginal people visited the site while the excavation was in progress. In 1990 a one by one metre square (labelled 4A) was excavated in 14 spits (excavation units) of about 6 cm each to a depth below surface of 96 cm (figure 6.1). In 1991 a second a one by one metre square (labelled 5B) was excavated in 31 spits (excavation units) of about 3 cm each to a depth of 90 cm. Excavation units were different depths in each square but I was able to identify equivalent excavation units between the two squares by analysing Strawbridge's depth measurements.

Figure 6.1 Plan of Cleft Rock Shelter. Redrawn from Strawbridge's field drawings and measurements. Section measurements were not available for Cleft Rock Shelter.

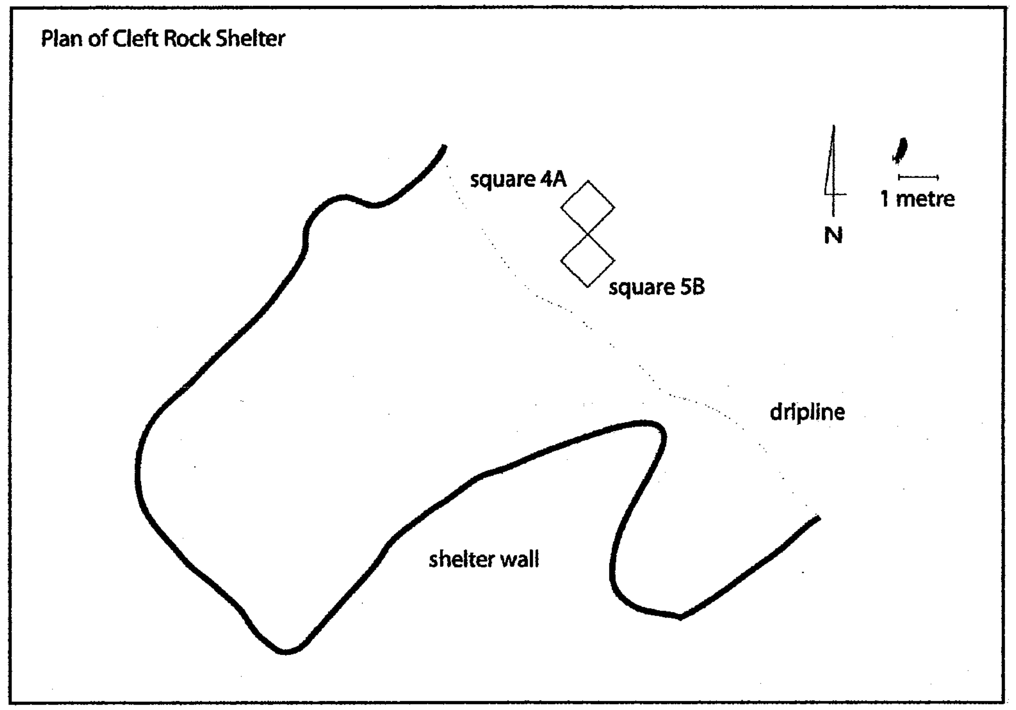
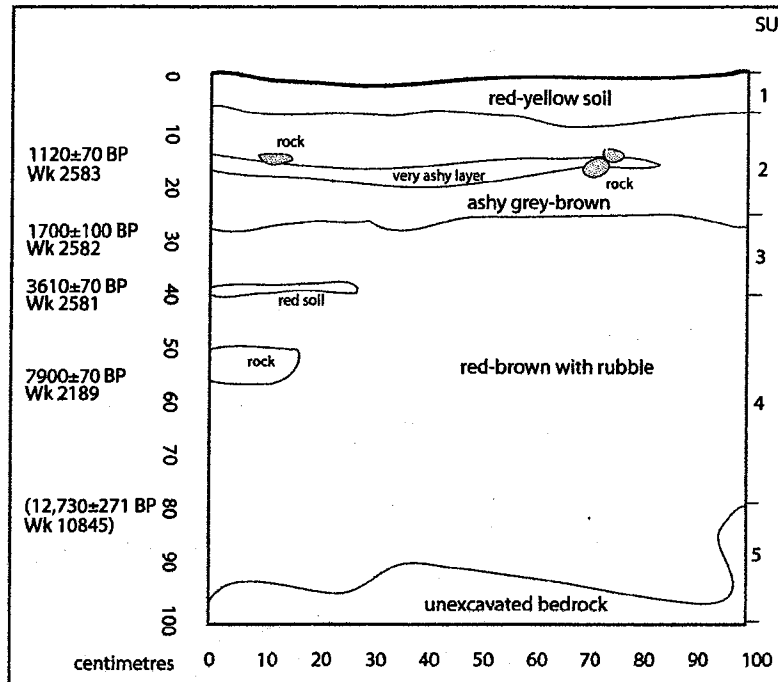


Figure 6.2 North section of excavated square 4A at Cleft Rock Shelter. Redrawn from Strawbridge's field drawings and measurements.

SU= stratigraphic unit
EU = excavation unit
field= measurement taken by Strawbridge in the field during excavation
lab= analysis undertaken under laboratory conditions during 2001-2
Date in brackets indicates that it was determined on charcoal from square 5B



SU	EU	pH field	pH lab	colour field	colour lab
1	1	4.5	6.6	2.5YR 4/4	5YR 4/4
	2	5	5.8	2.5YR 3/6	5YR 4/4
2	3	6	5.5	5YR 3/4	5YR 3/4
	4	6		2.5YR 4/6	
	5	5.5	5.5	2.5YR 4/4	5YR 3/4
3	6		5.8	2.5YR 3/6	5YR 3/4
	7	4.5	5.8	2.5YR 3/6	5YR 4/4
	8		5.8		5YR 4/4
	9		5.9		5YR 4/4
4	10	4.5	5.9	2.5YR 3/6	2.5YR 3/6
	11		6.2		2.5YR 3/6
	12	4.5	6.1	10R 3/6	2.5YR 3/6
	13		6.2		2.5YR 4/6
5	14		6.3		2.5YR 4/6
	15				

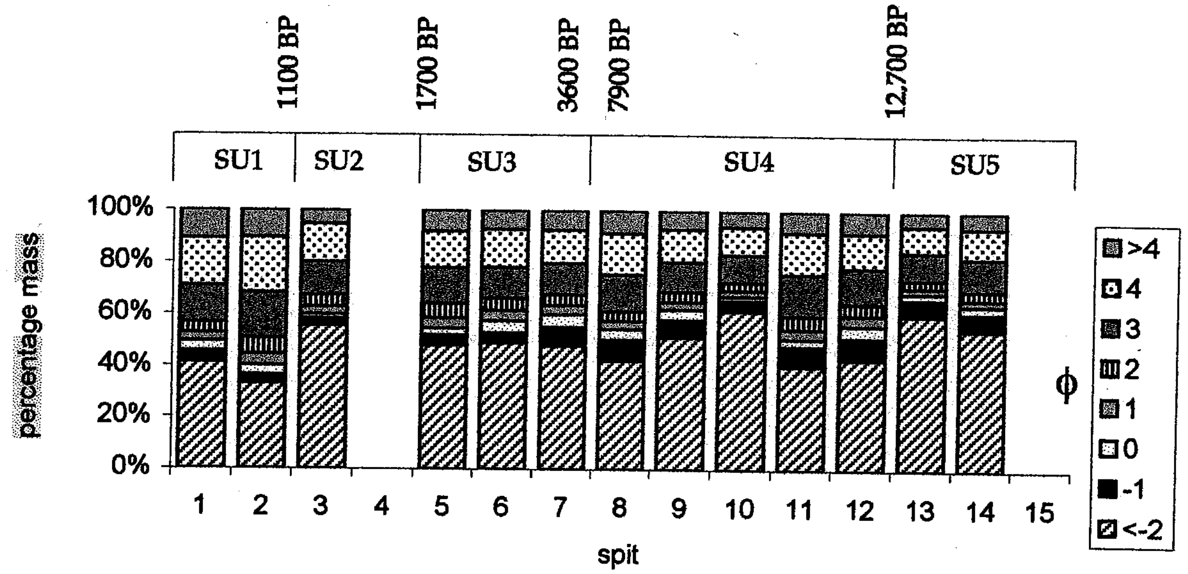
THE TIMING OF OCCUPATION

I used Strawbridge's field descriptions and the results of my analysis of sediments from square 4A to establish the timing of changes in site formation processes. I grouped excavation units with similar characteristics into stratigraphic units to identify evidence of human occupation that had formed under similar conditions. No sediment samples were available from square 5B.

The analysis of colour (figure 6.2) and particle size distributions of sediment samples (figure 6.3) from the available excavation units indicated that there were no major differences in the excavated sequence.

Figure 6.3 Particle size distribution at Cleft Rock Shelter square 4A. Particle size fractions expressed as phi.

SU = stratigraphic unit



The analysis of sediments suggests that the deposit at Cleft Rock Shelter formed with similar materials under similar conditions since the beginning of sediment accumulation in the rockshelter. The failure of the sediment analysis to show the stratigraphic units recorded by Strawbridge in her section drawing (figure 6.2) suggests that the techniques used may be insensitive to the differences observed by Strawbridge. If Strawbridge's observations were dependant of the specific conditions at the time and context of recording then I would expect deeper sediments to be darker because of increased moisture content with depth and evaporation of moisture near the surface. Strawbridge's record of soil colour shows that the change in soil colour with depth is only in hue (2.5YR to 10R), rather than value and chroma, indicating that deeper soil was not darker due to increased moisture content and surface evaporation. This suggests that the specific conditions at the time Strawbridge recorded the stratigraphy at Cleft Rock Shelter had a minimal influence on her observations.

From Strawbridge's notes I identified three stratigraphic units at square 4A and dated them by radiocarbon analysis of charcoal samples. Strawbridge obtained the four upper radiocarbon dates at square 4A shortly after excavation and I obtained another from near the base of square 5B in 2002. I decided to divide square 4A into five stratigraphic units based on the three units identified by Strawbridge and the radiocarbon dates in the homogenous lower red-brown rubble. By comparing changes in discard of cultural material within homogenous units I can produce a finer-grained description of the history of human use of the site and test the idea that changes in human activity are linked to stratigraphic changes at Cleft Rock Shelter.

Stratigraphic unit one was identified from Strawbridge's description of the upper 6 cm of the rockshelter as 'red-yellow soil', which is distinctive from the 'grey-brown ashy soil' at 6-31 cm below surface (figure 6.2, excavation units one and two). I identified the 'grey-brown ashy soil' as stratigraphic unit two (excavation units three and four). Strawbridge submitted charcoal collected in situ for two dates for stratigraphic unit two in 1990. The youngest date of 1120±70 BP (Wk 2583) comes from charcoal collected from about 10 cm below surface (excavation unit two). This date approximates the time when site formation conditions changed between stratigraphic units one and two. The second date of 1710±100 BP (Wk 2582) comes from charcoal collected from about 25 cm below surface (excavation unit four). This date is around the time that site formation conditions changed between stratigraphic units two and three.

I divided the homogenous 'red-brown soil' deposit below stratigraphic unit two in the three stratigraphic units based on the location of the two radiocarbon dates. In 1990 Strawbridge obtained a date of 3610±70 BP (Wk 2581) from charcoal collected *in situ* from about 40 cm below the surface (excavation unit seven) and a date of 7900±70 (Wk 2189) BP from charcoal collected *in situ* at a depth of about 50 cm below the surface (excavation unit eight). I identified stratigraphic unit three (excavation units five to seven) as the deposit from the top of the 'red-brown soil' deposit (30 cm below the surface) to the 3600 BP date (40 cm below the surface). The vertical closeness of the 3600 BP and 7900 BP dates indicate a 4300 year period of reduced sedimentation rates between the two dates, suggestive of an environmental change or a change in the occupation intensity of the shelter. The absence of change in particle size proportions over this period suggests that increased erosion levels were not responsible for the reduced sedimentation rate, so it is probable that human occupation was infrequent during this period.

I identified stratigraphic unit four (excavation units eight to 12) as the deposit between the 7900 BP date (50 cm below the surface) and the 12,700 BP date (80

cm below the surface). Prior to obtaining the 12,700 BP on charcoal from square 5B I had obtained an anomalous date of 701±69 BP (Wk 10199) from 0.8 g of charcoal collected from 3 mm sieve residue of sediments from 80 cm below surface of square 4A. Strawbridge (pers. comm. 2002) has suggested that this anomalous date may be a result of young surface charcoal falling to the base of the excavation while excavation was in progress. I identified stratigraphic unit five (excavation units 13-15) as the deposit from the 12,700 BP date (80 cm below the surface) to the base of the excavation (about 95 cm below the surface).

CHANGES IN THE INTENSITY AND TYPE OF OCCUPATION

Organic material and soluble salt concentration

I analysed rates of deposition of charcoal, soil organic material and soluble salt concentration at square 4A as possible measures of changes in the intensity of human occupation at Cleft Rock Shelter. Figure 6.4 shows the distribution of charcoal throughout the excavated deposit. A peak in charcoal occurs over excavation units seven to ten, suggesting that fires occurred at Cleft Rock Shelter during the period 3600 BP to after 7900 BP more frequently than other periods. In excavation units two and three, about 14-18 cm below surface and between the 1100 BP and 1700 BP dates, there is a small peak in charcoal. This probably corresponds to the thin layer identified by Strawbridge as 'grey ashy soil' in her section drawing (figure 6.2).

Figure 6.4 Charcoal density at Cleft Rock Shelter square 4A

SU = stratigraphic unit

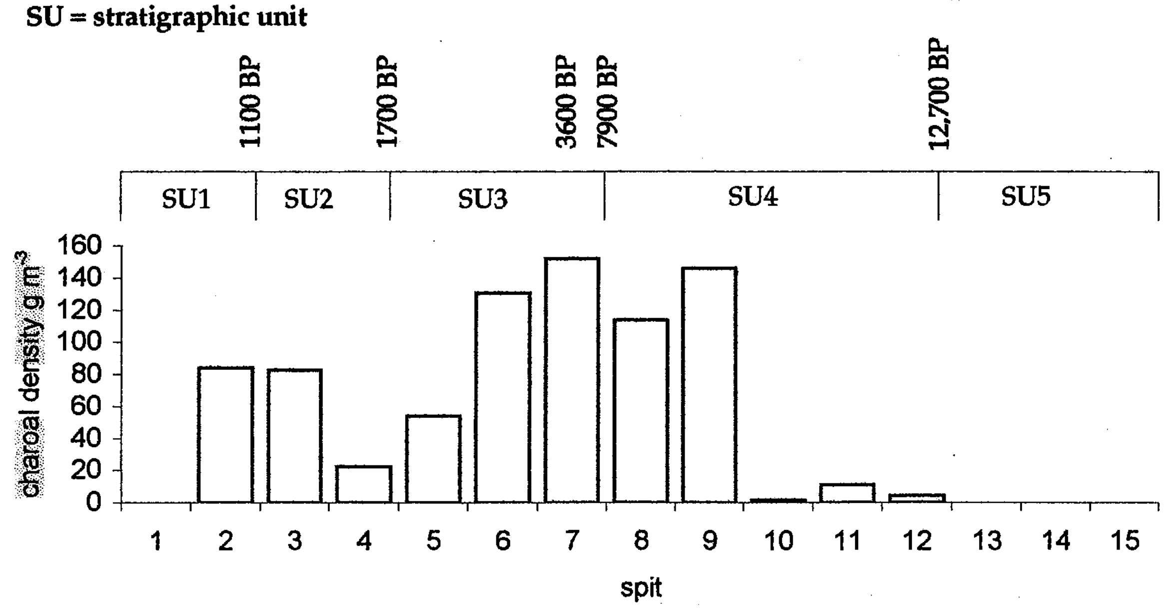
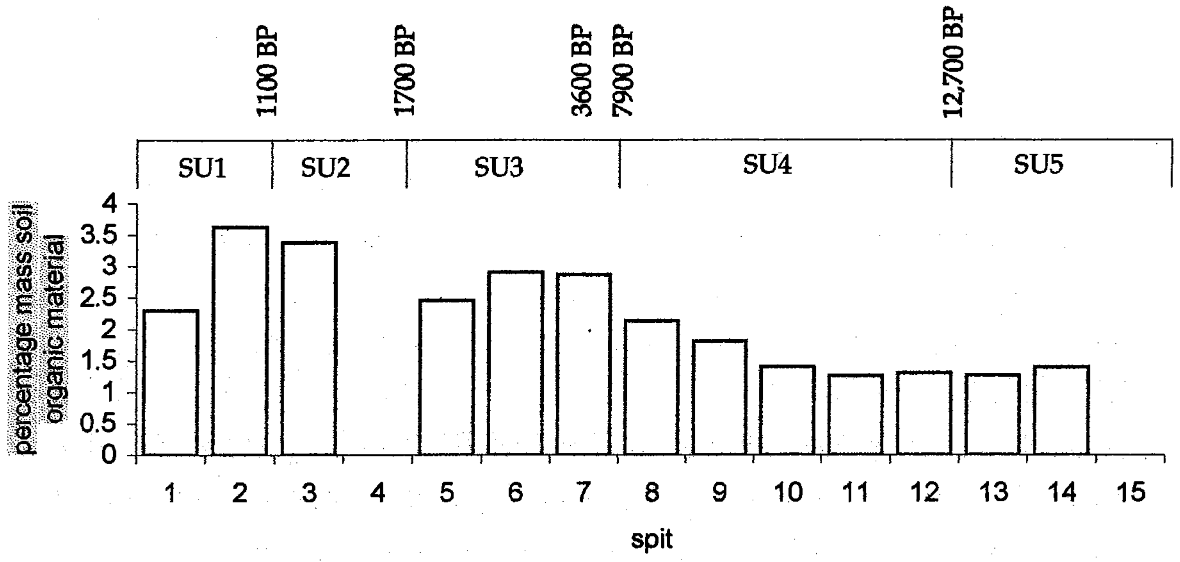


Figure 6.5 shows the percentage of soil organic matter in spits at square 4A. No sedimentary organic material was available for analysis from Cleft Rock Shelter. The distribution of soil organic matter peaks in the upper stratigraphic units suggesting that its distribution is sensitive to decay with age and depth. A secondary peak in stratigraphic unit three, between 1700 BP and 3600 BP, may reflect an increase in human use of the shelter.

Figure 6.5 Soil organic material distribution at Cleft Rock Shelter square 4A

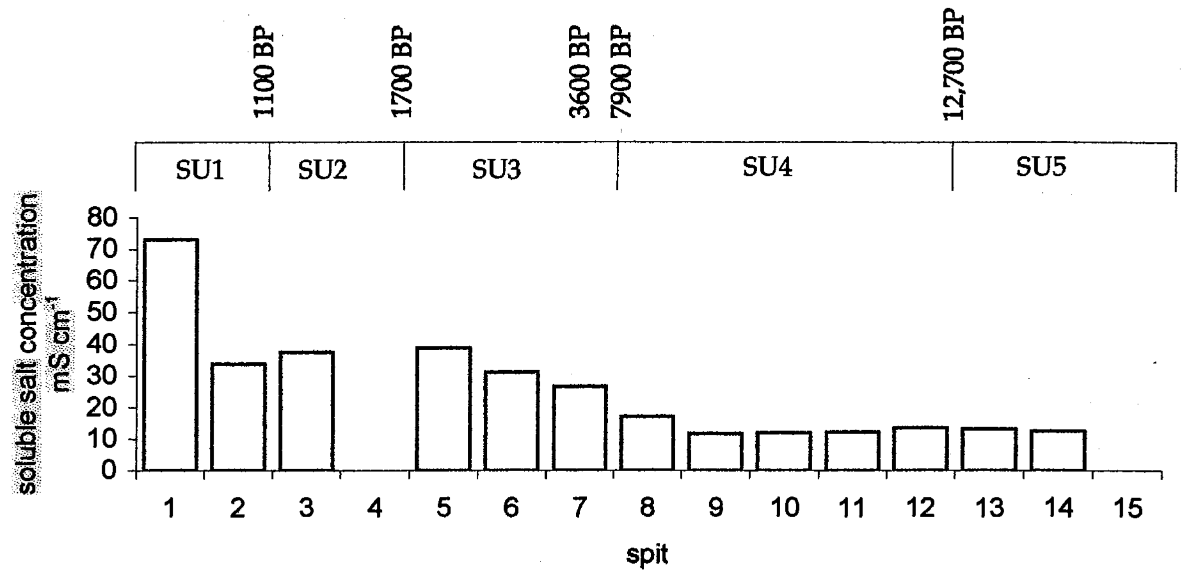
SU = stratigraphic unit



The concentration of soluble salts at square 4A peaks near the surface and at between 1100 BP and 1700 BP (figure 6.6). The soluble salt distribution is similar to the soil organic material distribution, suggesting a link between soluble salt concentration and organic material concentration. To summarise, the organic and soluble salt evidence suggests that occupation was most intensive between 1100 BP and 1700 BP. A second peak in occupation is indicated by the distribution of charcoal and soil organic material at between 3600 BP to about 7900 BP.

Figure 6.6 Soluble salt concentration at Cleft Rock Shelter square 4A

SU = stratigraphic unit



Stone artefacts

The stone artefact assemblages provide additional evidence on changes in the intensity of occupation of Cleft Rock Shelter. Figures 6.7-6.8 show the number of artefacts per cubic metre of sediment in square 4A and 5B. The discard graphs suggest that the site was continuously occupied with two periods of peak artefact discard. Figure 6.7 shows that stone artefact discard is highest in square 4A at excavation unit 12, which is in stratigraphic unit four at between 7900 BP and 12,700 BP. The rate of artefact discard in unit four at square 4A is relatively low at 4.9 artefacts per hundred years, indicating that the peak is discard was quite brief. Figure 6.8 shows that in square 5B artefact discard peaks at excavation unit 28. Analysis of excavation unit depths (note that the depths of excavation units very considerably within and between the two squares at Cleft Rock Shelter) from the two squares indicates that excavation unit 28 of square 5B and excavation unit 12 of square 4A are deposits from similar depths below the surface (about 80 cm).

A second peak in artefact discard occurs at about 1700 BP (excavation unit three) in square 4A. The rate of artefact discard at this second peak (between 1700 BP and 1100 BP) is 21.8 artefacts per hundred years, the highest rate of the sequence. In square 5B the second peak in discard also occurs around 1700 BP, based on the excavation unit depths from 5B and the depths of the dates in square 4A. The similar depths of the artefact discard peaks in the two square suggests similar dates for the peaks in artefact discard and indicate that the artefact discard pattern represents repeated patterns of behaviour rather than localised and isolated events within the rockshelter. Between the two peaks in discard (7900 BP to 1700 BP) the rate of artefact discard is 3.5 artefacts per hundred years.

The most recent peak in artefact discard falls within the age range of a peak in occupation indicated by organic and soluble salt evidence (1700 BP to 3600 BP), but the second artefact discard peak (around 12,700 BP) is not synchronous with the second peak in the organic, charcoal and soluble salts evidence (3600 BP to 7900 BP). This suggests that either one of the two late Holocene peaks in stone artefact density and other evidence was not caused by human occupation or, more likely, that post-depositional forces have affected stone artefacts and other evidence in different ways.

Figure 6.7 Stone artefact discard at Cleft Rock Shelter square 4A (n= 577)

SU = stratigraphic unit

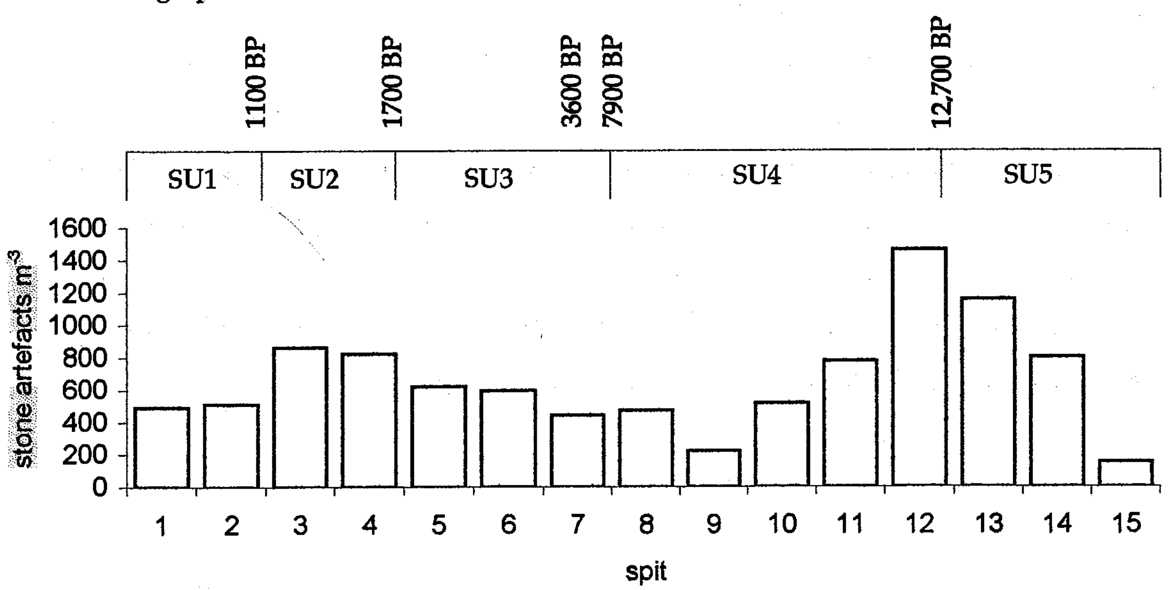
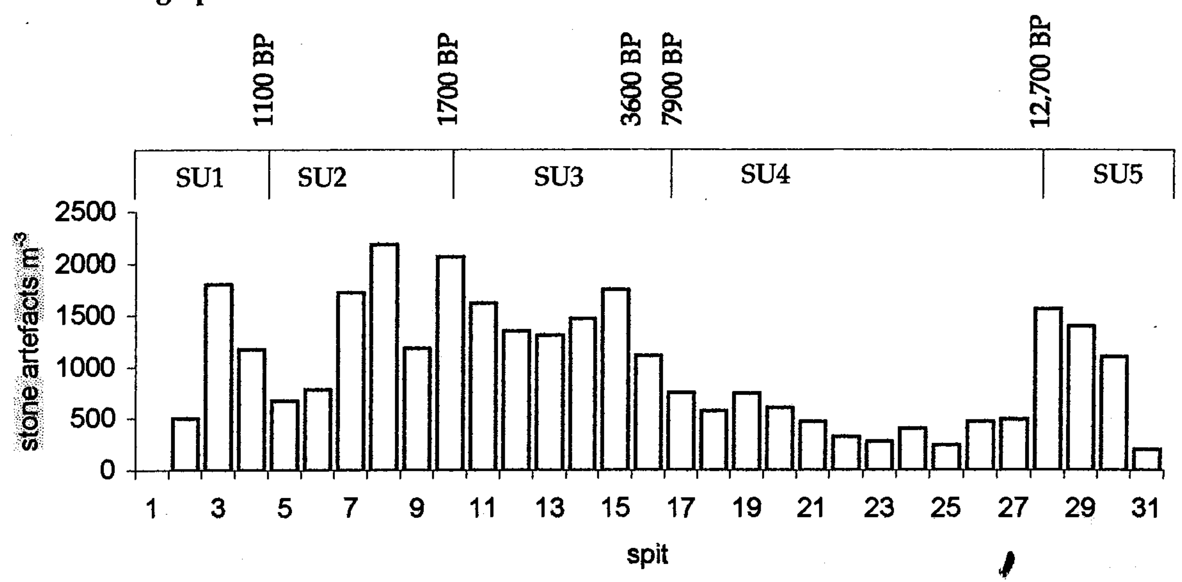


Figure 6.8 Stone artefact discard at Cleft Rock Shelter square 5B (n = 804). The designation of stratigraphic units is conjectural because of the absence of sediments for analysis from square 5B.

SU = stratigraphic unit



To identify the causes of the peaks in stone artefact discard I analysed the stone artefacts to show the influence of post-depositional change, changes in artefact manufacturing technology and changes in the function of the site. I analysed the stone artefacts from square 4A only because of the limited comparable stratigraphic and sedimentary evidence from square 5B.

Post-depositional change

To see whether post-depositional processes were the cause of the changes in artefact density, and whether these post-depositional processes had affected the units to different degrees, I measured artefact breakage using the Sullivan and Rozen typology. Table 6.1 shows the numbers of each debitage type for each stratigraphic unit in square 4A.

Table 6.1 Debitage analysis of stone artefacts from Cleft Rock Shelter square 4A

SU = stratigraphic unit
n = number of artefacts
$\%_1$ = percent of total artefacts recovered from the site
$\%_2$ = percent of total artefacts recovered from stratigraphic unit

SU	total artefacts		complete flake		broken flake (long)		broken flake (trans)		flake fragment		angular piece	
	n	$\%_1$	n	$\%_2$	n	$\%_2$	n	$\%_1$	n	$\%_1$	n	$\%_1$
1	54	9.4	10	18.5	0	0.0	0	0.0	15	27.8	30	55.6
2	107	18.5	23	21.5	0	0.0	1	0.9	38	35.5	45	42.1
3	110	19.1	30	27.3	0	0.0	5	4.5	39	35.5	36	32.7
4	239	41.4	79	33.1	6	2.5	2	0.8	80	33.5	72	30.1
5	67	11.6	24	35.8	0	0.0	3	4.5	23	34.3	17	25.4

Chi-square tests summarised in table 6.2 show that there are no significant differences in the numbers of debitage types between the five stratigraphic units. This suggests that all stratigraphic units were similarly affected by post-depositional processes.

Table 6.2 Chi-square tests on differences in the numbers of each debitage type between stratigraphic units at Cleft Rock Shelter Square 4A

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

SU	χ^2	df	$p(H_0)$	reject H_0?
1:2	2.687	3	0.442	no
2:3	4.563	3	0.206	no
3:4	1.348	3	0.717	no
4:5	0.722	3	0.867	no

I identified a conjoin between six chalcedony flakes and a chalcedony core in the northeast quadrant of excavation unit five and a conjoin of two siltstone flake fragments in the southeast quadrant of excavation unit 10. The close proximity of the conjoin pieces suggests that post depositional disturbance at Cleft Rock Shelter was minimal and stratigraphic integrity is high. The debitage analysis and conjoin evidence suggest that post-depositional disturbance at Cleft Rock Shelter has been uniformly low throughout the history of its occupation and that post-depositional processes cannot explain the changes in stone artefact discard.

Artefact manufacture

Raw materials

If changes in post-depositional conditions do not explain the change in artefact discard then the changes may be due to some aspect of human use of the stone or use of the site. Raw material is important in determining the fracture mechanics of rock so I analysed changes in the numbers of artefacts made from chert and siltstone, the two most abundant raw materials at Cleft Rock Shelter, to see whether raw material changes caused the changes in artefact discard. Table 6.3 shows the number of stone artefacts for each raw material found in the five stratigraphic units.

Table 6.3 Raw material of stone artefacts at Cleft Rock Shelter Square 4A

SU = stratigraphic unit
n = number of artefacts
$\%_1$ = percent of total artefacts recovered from the site
$\%_2$ = percent of total artefacts recovered from stratigraphic unit

SU	total artefacts		chert		siltstone		ironstone		quartz		chalcedony		others	
	n	$\%_1$	n	$\%_2$	n	$\%_2$	n	$\%_1$	n	$\%_1$	n	$\%_1$	n	$\%_1$
1	54	9.4	40	74.1	12	22.2	0	0.0	0	0.0	1	1.9	1	1.9
2	107	18.5	80	74.8	21	19.6	0	0.0	4	3.7	2	1.9	0	0.0
3	110	19.1	52	47.3	49	44.5	2	1.8	0	0.0	7	6.4	0	0.0
4	239	41.4	54	22.6	173	72.4	8	3.3	2	0.8	2	0.8	0	0.0
5	67	11.6	9	13.4	54	80.6	3	4.5	0	0.0	0	0.0	1	1.5

Tables 6.4 - 6.5 show that the changes in numbers of siltstone and chert artefacts between stratigraphic units two, three and four are significant. Chert artefacts become more abundant and siltstone artefacts become less abundant from 7900 BP to 1700 BP. Siltstone and chert are both fine-grained silicious rocks formed by sedimentary processes (Pellant 1992:232, 246). The difference is that siltstone is a clastic sedimentary rock and chert is a chemical precipitate sedimentary rock (Andrefsky 1998:50-52). The similar sized grains means that siltstone and chert both have similar degrees of predictability and control during flaking but the difference in sedimentary processes means that chert is a harder and more brittle rock (Andrefsky 1998:51).

Table 6.4 Chi-square tests on differences in the numbers of chert artefacts between stratigraphic units at Cleft Rock Shelter Square 4A

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true
ϕ= Phi coefficient (direction of association)
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

SU	χ^2	df	$p(H_0)$	reject H_0?	ϕ	C_{adj}
1:2	0.078	1	0.779	no	na	na
2:3	17.194	1	3.35×10^{-5}	yes	0.281	0.365
3:4	21.791	1	3.2×10^{-6}	yes	0.249	0.332
4:5	2.686	1	0.101	no	na	na

Table 6.5 Chi-square tests on differences in the numbers of siltstone artefacts between stratigraphic units at Cleft Rock Shelter Square 4A

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true
ϕ= Phi coefficient (direction of association)
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

SU	χ^2	df	$p(H_0)$	reject H_0?	ϕ	C_{adj}
1:2	0.352	1	0.552	no	na	na
2:3	15.411	1	8.64×10^{-5}	yes	-0.266	0.347
3:4	24.366	1	5.11×10^{-7}	yes	-0.268	0.350
4:5	1.842	1	0.174	no	na	na

The increased use of chert from 7900 BP to 1700 BP may be a reaction to changes in the availability of siltstone and chert, changes in artefact manufacturing technology and use that require harder rock or an isochrestic decision made by artefact manufacturers unrelated to function. To determine which of these explanations is the most plausible, changes in the technology of artefact manufacture were analysed as well as changes in the proportions of resharpened artefacts for chert and siltstone artefacts.

Technological variables

To test for changes in artefact manufacturing technology between the five units, and see whether the difference in hardness between chert and siltstone or changes in raw material availability are responsible for changes in artefact discard, I analysed technological variables on chert complete flakes (table 6.6) and siltstone complete flakes (table 6.7) at Cleft Rock Shelter. Table 6.6 shows that the frequency of chert flakes with overhang removal and the number of

flakes with more than one flake scar is significantly higher during 3600 - 1700 BP compared to the preceding period between 12,700 and 7900 BP. Increased platform preparation suggests that core platforms were prepared to maximise the probability of producing usable flakes and increased flake scars suggests that more flakes were extracted from cores. These economising measures may reflect a change in technology in response to a restriction in raw material availability. Curiously, table 6.8 shows that the mass of chert artefacts *increases* after 7900 BP, suggesting that artefact sizes were not reduced to conserve raw material. This indicates that technological changes in response to a restriction in raw material availability do not convincingly explain the change in discard rates of chert at after 7900 BP. There are no significant changes in chert metric variables suggesting there was no change towards the production of more blade-like flakes at any time at Cleft Rock Shelter.

The changes in chert metric variables after 1100 BP are difficult to interpret because the 0-1100 BP sample consists of only five artefacts (table 6.8, figures 6.9-6.13), which may represent a single knapping event and not be representative of long-term patterns of behaviour.

Changes in the technology of siltstone artefact manufacture show a similar pattern to chert artefacts (table 6.7). Frequency of flakes with evidence of overhang removal and more than one dorsal flake scar increase after 7900 BP, indicating the application of techniques related to economising raw material use in stone artefact manufacture. Metric data on siltstone flakes also show that coincident with the apparent economising technology is a significant increase in artefact size at after 3600 BP, which is unexpected if the technological changes indicate a restriction in the availability of siltstone (table 6.9, figures 6.14-6.18). After 1700 BP siltstone flakes decrease in three of the five metric dimensions measured. This is not coincident with any indicators of increased technological efficiency similar to those at 3600 BP. The technological and metric evidence for siltstone artefacts suggests that, like chert artefacts, restrictions in raw material availability do not convincingly explain the changes in raw materials and discard rates.

If increased tool resharpening activity is the cause of the increased proportions of chert artefacts (because of its suitability for retouching) after 7900 BP and again after 3600 BP then significant reductions in artefact size should appear in the assemblages at these times because flakes produced from retouch are identifiable by their short length (Cotterell and Kamminga 1990, Newcomer and Karlin 1987). The absence of any significant change after 7900 BP and the increase in the size of siltstone and chert after 3600 BP suggest that the frequency of tool resharpening did not increase with the increased number of chert artefacts.

Artefacts made from raw materials other than chert and siltstone show no change in metric variables (table 6.10). There were only three flakes made from raw materials other than chert or siltstone (table 6.10) so I did not include them in the analysis.

Table 6.6 Summary of technological analysis of chert flakes from Cleft Rock Shelter square 4A

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit											
		1		2		3		4					
	years BP	0-1100		1100-1700		1700-3600		7900-12,700					
	number of chert complete flakes	5		14		12		9					
	% of all flakes that are chert	50.0		60.9		40.0		11.4					
										significant change in variable?			
		n	%	n	%	n	%	n	%	reject H_0?	C_{adj}	when?	direction?
termination	feather	4	80.0	11	78.5	9	75.0	9	100.0	no	na	na	na
platform surface	flat	1	20.0	6	42.8	5	41.7	4	44.4	no	na	na	na
	facetted	3	60.0	5	35.7	6	50.0	3	33.3	no	na	na	na
	cortical	1	20.0	2	14.2	1	8.3	2	22.2	no	na	na	na
platform type	wide	5	100.0	13	92.8	12	100.0	6	66.7	yes	0.603	SU4:5 12,000 BP	increase
	focalised	0	0.0	0	0	0	0.0	1	11.1	na	na	na	na
	gull	1	20.0	0	0	1	8.3	0	0.0	na	na	na	na
overhang removal	flakes with overhang removal	2	40.0	9	64.2	4	33.3	4	44.4	no	na	na	na
reduction level	flakes with >1 dorsal flake scar	2	40.0	8	57.1	4	33.3	2	22.2	no	na	na	na
	flakes with distal and lateral flake scars	0	0.0	0	0	0	0.0	1	11.1	na	na	na	na
	flakes with <10 cortex	1	20.0	7	50	8	66.7	7	77.8	no	na	na	na
	flakes with 10-50 cortex	4	80.0	4	28.5	1	8.3	1	11.1	yes	0.589	SU1:2 1100BP	increase
	flakes with >50 cortex	0	0.0	1	7.1	3	25.0	1	11.1	no	na	na	na

Table 6.7 Summary of technological analysis of siltstone flakes from Cleft Rock Shelter square 4A

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit 1		2		3		4		5		significant change in variable?			
	years BP	0-1100		1100-1700		1700-3600		7900-12,700		>12,700					
	number of siltstone complete flakes	4		7		18		68		24					
	% of all flakes that are siltstone	40		30.4		60.0		86.0		100					
		n	%	n	%	n	%	n	%	n	%	reject H_0?	C_{adj}	when?	direction?
termination	feather	2	50.0	6	85.7	11	61.1	51	75.0	21	87.5	no	na	na	na
platform surface	flat	3	75.0	3	42.9	9	50.0	32	47.1	13	54.2	no	na	na	na
	facetted	1	25.0	2	28.6	6	33.3	18	26.5	9	37.5	no	na	na	na
	cortical	0	0.0	2	28.6	3	16.7	18	26.5	2	8.3	no	na	na	na
platform type	wide	4	100.0	7	100.0	16	88.9	57	83.8	20	83.3	no	na	na	na
	focalised	0	0.0	0	0.0	2	11.1	5	7.4	4	16.7	no	na	na	na
	gull	0	0.0	0	0.0	0	0.0	4	5.9	0	0.0	no	na	na	na
overhang removal	flakes with overhang removal	2	50.0	4	57.1	12	66.7	24	35.3	8	33.3	yes	0.354	SU3:4 3600-7900 BP	increase
reduction level	flakes with >1 dorsal flake scar	1	25.0	2	28.6	7	38.9	10	14.7	6	25.0	yes	0.339	SU3:4 3600-7900 BP	increase
	flakes with distal and lateral flake scars	0	0.0	0	0.0	1	5.6	0	0.0	1	4.2	no	na	na	na
	flakes with <10 cortex	1	25.0	3	42.9	8	44.4	41	60.3	15	62.5	no	na	na	na
	flakes with 10-50 cortex	0	0.0	1	14.3	13	72.2	36	52.9	10	41.7	yes	0.656	SU2:3 1700 BP	decrease
	flakes with >50 cortex	1	25.0	0	0.0	1	5.6	8	11.8	5	20.8	no	na	na	na

Table 6.8 Summary of metric analysis of chert flakes from Cleft Rock Shelter square 4A

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t- tests

		stratigraphic unit	1	2	3	4	5
		time period	0-1100	1100-1700	1700-3600	7900-12,700	>12,700
		total number of chert artefacts	40	80	52	54	9
		total number of chert flakes	5	14	12	9	0
mass of total artefacts		mean (g)	10.22	3.19	7.98	2.63	6.961
	significant change?	t	3.357	-3.581	3.307	-0.565	na
		$p(H_0)$	0.001	0.0004	0.001	0.574	na
		reject H_0?	yes - increase	yes - decrease	yes - increase	no	na
flake length		mean (mm)	24.32	28.56	24.56	16.40	0
	significant change?	t	-0.507	0.721	1.453	na	na
		$p(H_0)$	0.618	0.477	0.162	na	na
		reject H_0?	no	no	no	na	na
flake width		mean (mm)	30.58	19.25	19.72	20.08	0
	significant change?	t	1.812	0.205	0.459	na	na
		$p(H_0)$	0.087	0.838	0.651	na	na
		reject H_0?	no	no	no	na	na
flake thickness		mean (mm)	10.34	5.96	6.23	6.24	0
	significant change?	t	2.106	0.206	1.285	na	na
		$p(H_0)$	0.050	0.837	0.214	na	na
		reject H_0?	no	no	no	na	na
flake mass		mean (g)	15.23	4.12	6.46	4.99	0
	significant change?	t	1.882	0.122	1.370	na	na
		$p(H_0)$	0.077	0.903	0.186	na	na
		reject H_0?	no	no	no	na	na
flake platform width		mean (mm)	29.46	11.39	13.26	14.98	0
	significant change?	t	3.059	-0.702	1.390	na	na
		$p(H_0)$	0.007	0.489	0.180	na	na
		reject H_0?	yes - increase	no	no	na	na
flake platform thickness		mean (mm)	10.56	4.09	4.18	5.04	1
	significant change?	t	3.202	0.511	1.013	na	na
		$p(H_0)$	0.005	0.613	0.323	na	na
		reject H_0?	yes - increase	no	no	na	na

Table 6.9 Summary of metric analysis of siltstone flakes from Cleft Rock Shelter square 4A

t= **t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)**

$p(H_0)$= **probability that the null hypothesis (that there is no difference) is true, calculated by t-tests**

	stratigraphic unit	1	2	3	4	5
	time period	0-1100	1100-1700	1700-3600	7900-12,700	>12,700
	total number of siltstone artefacts	12	21	49	173	54
	total number of siltstone flakes	3	13	105	68	24
mass of total artefacts	mean (g)	29.2	6.4	14.1	4.8	2.6
	significant change? t	1.958	0.001	3.223	1.682	na
	$p(H_0)$	0.059	0.999	0.001	0.093	na
	reject H_0?	no	no	yes - increase	no	na
flake length	mean (mm)	23.0	22.8	33.0	21.8	20.6
	significant change? t	0.370	-2.096	3.500	0.308	na
	$p(H_0)$	0.719	0.047	0.0007	0.758	na
	reject H_0?	no	yes - decrease	yes - increase	no	na
flake width	mean (mm)	25.7	20.3	26.1	19.2	16.3
	significant change? t	1.128	-1.022	2.528	1.092	na
	$p(H_0)$	0.288	0.317	0.013	0.277	na
	reject H_0?	no	no	yes - increase	no	na
flake thickness	mean (mm)	7.5	4.9	9.0	5.1	4.5
	significant change? t	1.699	-2.110	3.544	0.723	na
	$p(H_0)$	0.123	0.045	0.0006	0.471	na
	reject H_0?	no	yes - decrease	yes - increase	no	na
flake mass	mean (g)	5.6	4.2	19.1	6.7	4.4
	significant change? t	1.092	-1.972	3.709	1.086	na
	$p(H_0)$	0.303	0.060	0.0003	0.280	na
	reject H_0?	no	yes - decrease	yes - increase	no	na
flake platform width	mean (mm)	22.1	13.0	15.3	13.2	9.3
	significant change? t	1.793	-0.445	1.029	2.359	na
	$p(H_0)$	0.106	0.660	0.306	0.020	na
	reject H_0?	no	no	no	yes - increase	na
flake platform thickness	mean (mm)	7.3	4.2	6.7	4.3	2.8
	significant change? t	1.747	-1.225	2.081	2.549	na
	$p(H_0)$	0.114	0.232	0.040	0.012	na
	reject H_0?	no	no	yes - increase	yes - increase	na

Figure 6.9 Frequency distribution of chert flake lengths in unit one of Cleft Rock Shelter square 4A

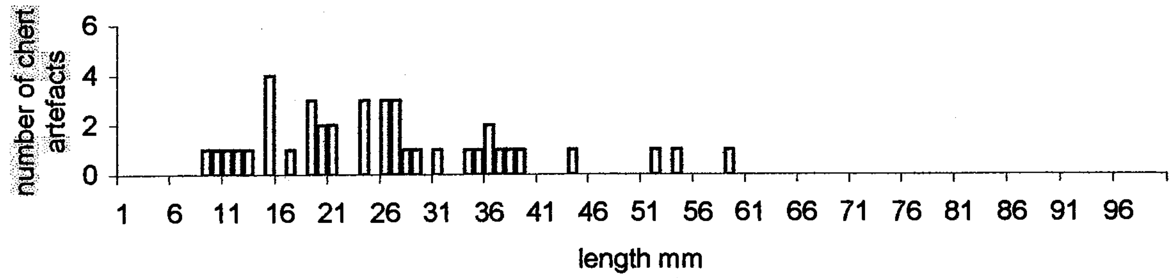


Figure 6.10 Frequency distribution of chert flake lengths in unit two of Cleft Rock Shelter square 4A

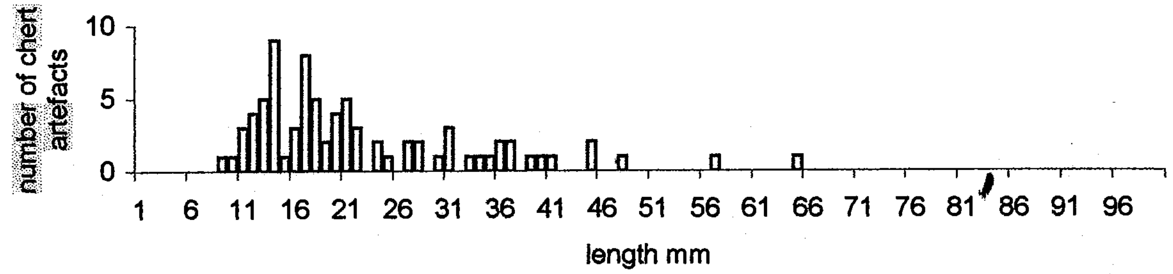


Figure 6.11 Frequency distribution of chert flake lengths in unit three of Cleft Rock Shelter square 4A

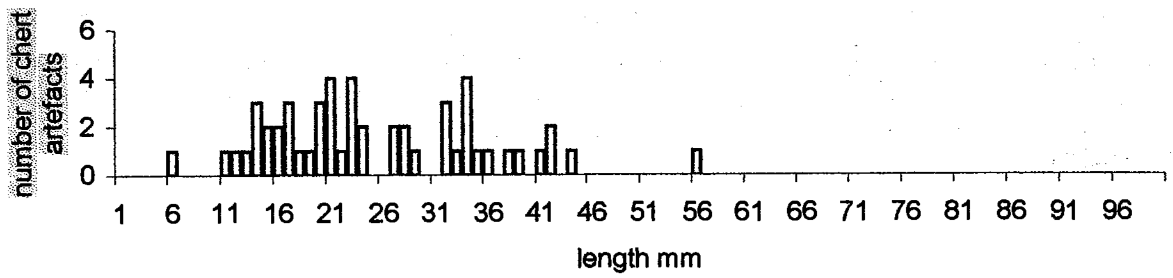


Figure 6.12 Frequency distribution of chert flake lengths in unit four of Cleft Rock Shelter square 4A

Figure 6.13 Frequency distribution of chert flake lengths in unit five of Cleft Rock Shelter square 4A

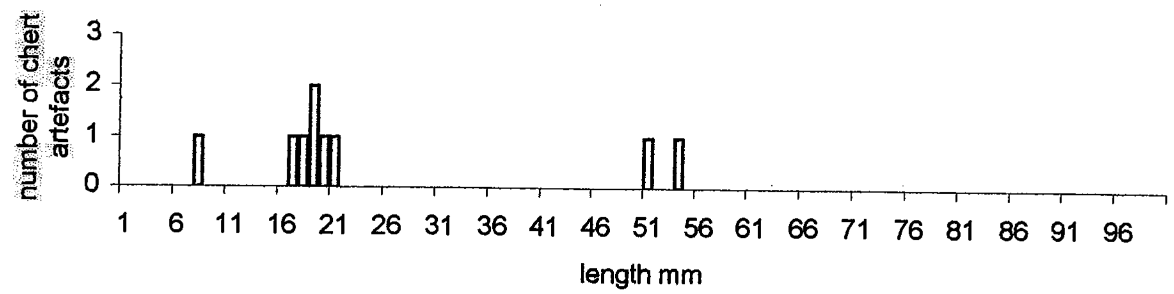


Figure 6.14 Frequency distribution of siltstone flake lengths in unit one of Cleft Rock Shelter square 4A

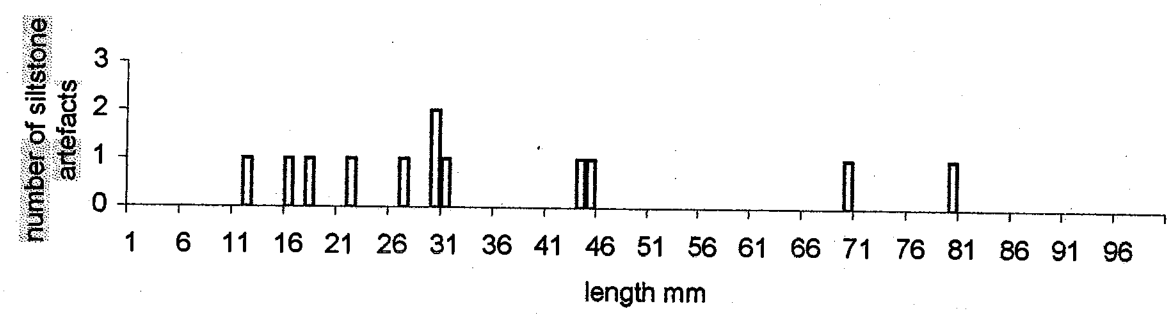


Figure 6.15 Frequency distribution of siltstone flake lengths in unit two of Cleft Rock Shelter square 4A

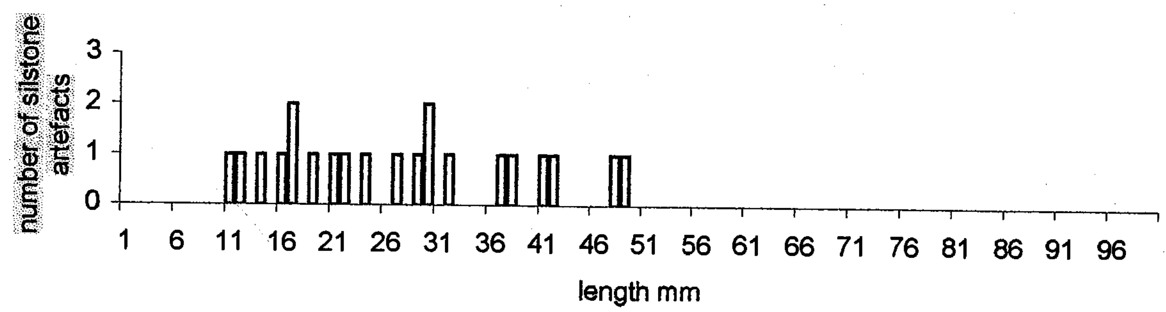


Figure 6.16 Frequency distribution of siltstone flake lengths in unit three of Cleft Rock Shelter square 4A

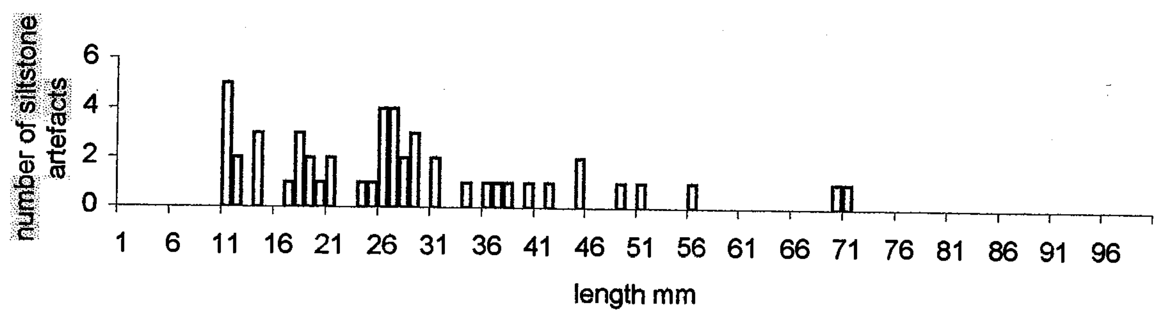


Figure 6.17 Frequency distribution of siltstone flake lengths in unit four of Cleft Rock Shelter square 4A

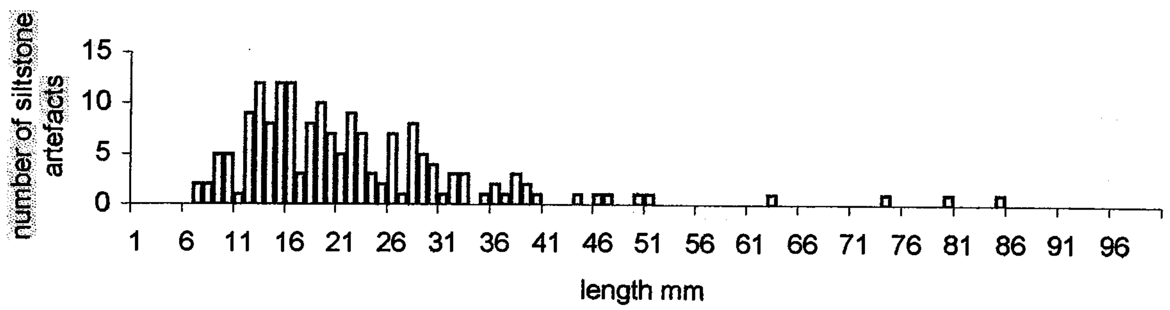


Figure 6.18 Frequency distribution of siltstone flake lengths in unit five of Cleft Rock Shelter square 4A

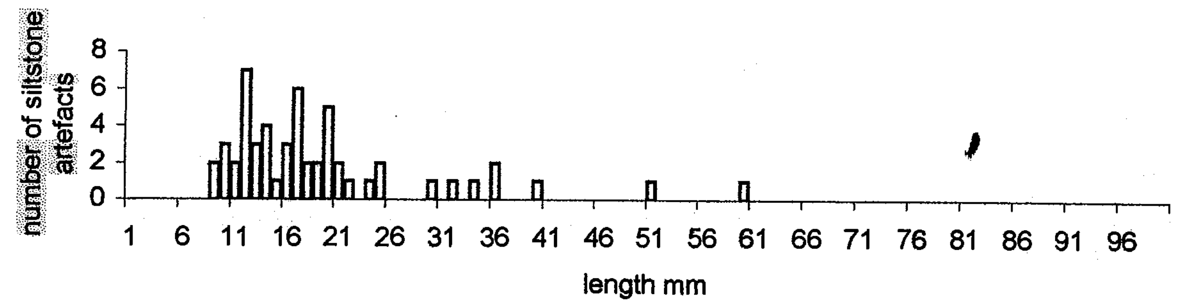


Table 6.10 Summary of metric analysis of flakes made from raw materials other than chert and siltstone from Cleft Rock Shelter square 4A

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)

p(H$_0$)= probability that the null hypothesis (that there is no difference) is true, calculated by t-tests

		stratigraphic unit	1	2	3	4	5
		time period	0-1100	1100-1700	1700-3600	7900-12,700	>12,700
		total number of other artefacts	2	6	9	13	4
		total number of other flakes	0	2	0	1	0
mass of total artefacts		mean (g)	1.3	1.0	5.6	1.7	1.1
	significant change?	t	0.860	-1.125	0.546	1.192	na
		p(H$_0$)	0.422	0.280	0.590	0.251	na
		reject H$_0$?	no	no	no	no	na

To see whether the technological changes indicative of increased efficiency were a result of increased standardisation of shape and size in artefact manufacture, possibly associated with the first appearance of new artefact types, I calculated the probabilities of significant differences in variances of length, width and thickness for chert and siltstone artefacts between stratigraphic units at square 4A. A more standardised assemblage should be distinguishable from less standardised assemblages by lower variance in metric variables. I used the *F* test for two population variances (Sheskin 2000:253-7) to see if there were significant differences in the variances of length, width and thickness of complete flakes. Tables 6.11 and 6.12 show that there are no significant differences in variance of dimensions of chert and siltstone complete flakes. This suggests that standardisation of artefacts does not explain the technological and raw material changes at Cleft Rock Shelter.

Figure 6.11 Summary of differences in variance in length, width and thickness of chert complete flakes from Cleft Rock Shelter

SU = stratigraphic unit
$p(H_0)$ = probability that the null hypothesis (that there is no difference in variance) is true, calculated by *F* tests

SU	length		width		thickness	
	$p(H_0)$	reject H_0?	$p(H_0)$	reject H_0?	$p(H_0)$	reject H_0?
1:2	0.383	no	0.382	no	0.114	no
2:3	0.343	no	0.210	no	0.146	no
3:4	0.285	no	0.379	no	0.291	no
4:5	na	na	na	na	na	na

Figure 6.12 Summary of differences in variance in length, width and thickness of siltstone complete flakes from Cleft Rock Shelter

SU = stratigraphic unit
$p(H_0)$ = probability that the null hypothesis (that there is no difference in variance) is true, calculated by *F* tests

SU	length		width		thickness	
	$p(H_0)$	reject H_0?	$p(H_0)$	reject H_0?	$p(H_0)$	reject H_0?
1:2	0.204	no	0.250	no	0.091	no
2:3	0.170	no	0.102	no	0.516	no
3:4	0.100	no	0.210	no	0.299	no
4:5	0.387	no	0.302	no	0.472	no

To summarise the evidence on artefact technology and metrics from the Cleft Rock Shelter sample, there is evidence of changes in metric and technological variables related to technology of artefact manufacture over time, but these

changes are not convincingly explained by greater efficiency of manufacture in response to restriction in raw material availability, a preference for harder raw material for resharpening or increased standardisation of artefact shape and size. This evidence suggests that the discard peaks at 1100-1700 BP and about 12,700 BP and the increased use of chert and decreased use of siltstone are unrelated to changes in the technology of artefact manufacture at Cleft Rock Shelter. These changes may be due instead to increases in the frequency and duration of occupation at Cleft Rock Shelter that did not require much technological reorganisation.

Change in the function of the site

To investigate whether increases in artefact discard at Cleft Rock Shelter were caused by changes in the function of the site, I compared the numbers of artefacts with secondary working in the five units. If the increased use of chert in later periods is a response to a need for tools with a longer life for changes in tasks that do not necessarily affect artefact manufacturing technology, such as plant and animal processing, then a higher number of artefacts with retouch/usewear is expected after 3600 BP and again after 1700 BP.

Table 6.13 shows that there are no significant changes in the numbers of artefacts with secondary working. Similarly, tables 6.14 to 6.16 show that there are no significant changes in numbers of artefacts with secondary working for chert, siltstone and other raw materials. The low number of backed artefacts and cores in each stratigraphic unit at Cleft Rock Shelter support the finding of the technological evidence that there were no substantial changes in artefact manufacturing technology over time. Backed artefacts first appear at Cleft Rock Shelter between 1100 BP and 1700 BP (one in excavation unit one and one in excavation unit three), 1900 years after their first appearance in the inland Pilbara at Newman Rockshelter. The appearance of backed artefacts at Cleft Rock Shelter coincides with a peak in stone artefact discard at 1100-1700 BP and an increase in the size of chert flakes, but is not related to any significant changes in technology or raw materials. This suggests that the first appearance of backed artefacts had little impact on stone artefact manufacturing and use, but may have been related to changes in the frequency and duration of site use.

Table 6.13 Summary of all artefacts with evidence of secondary working and cores from Cleft Rock Shelter square 4A

χ^2= chi-square
p(H_0)= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3	4	5
years BP	0-1100	1100-1700	1700-3600	7900-12,700	>12,700
total number of artefacts	54	107	110	239	67
total number of artefacts with retouch/usewear	12	12	7	9	3
number of artefacts with retouch/usewear that are backed	1	1	0	0	0
total number of cores	0	2	4	2	0
% of artefacts with retouch/usewear	22.2	11.2	6.4	3.8	4.5
χ^2	3.428	1.598	1.162	0.070	na
p(H_0)	0.064	0.206	0.280	0.790	na
reject H_0?	no	no	no	no	na

Table 6.14 Summary of chert artefacts with evidence of secondary working and cores from Cleft Rock Shelter square 4A

χ^2= chi-square
p(H_0)= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3	4	5
years BP	0-1100	1100-1700	1700-3600	7900-12,700	>12,700
total number of chert artefacts	40	80	52	54	9
total number of chert artefacts with retouch/usewear	9	10	4	1	1
number of chert artefacts with retouch/usewear that are backed	0	1	0	0	0.0
total number of chert cores	0	2	1	0	0
% of chert artefacts with retouch/usewear	22.5	12.5	7.7	0	0
χ^2	2.001	0.768	2.010	2.152	na
p(H_0)	0.157	0.381	0.156	0.142	na
reject H_0?	no	no	no	no	na

Table 6.15 Summary of siltstone artefacts with evidence of secondary working and cores from Cleft Rock Shelter square 4A

χ^2= chi-square
p(H_0)= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3	4	5
years BP	0-1100	1100-1700	1700-3600	7900-12,700	>12,700
total number of siltstone artefacts	12	21	49	173	54
total number of siltstone artefacts with retouch/usewear	2	2	3	8	2
number of siltstone artefacts with retouch/usewear that are backed	0	0	0	0	0
total number of siltstone cores	0	0	2	2	0
% of siltstone artefacts with retouch/usewear	16.7	9.5	6.1	4.6	3.7
χ^2	0.366	0.256	0.181	0.082	na
p(H_0)	0.545	0.613	0.669	0.773	na
reject H_0?	no	no	no	no	na

Table 6.16 Summary of artefacts made from raw materials other than chert and siltstone with evidence of secondary working and cores from Cleft Rock Shelter square 4A

χ^2= chi-square
p(H_0)= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3	4	5
years BP	0-1100	1100-1700	1700-3600	7900-12,700	>12,700
total number of other artefacts	2	6	9	12	4
total number of other artefacts with retouch/usewear	1	1	0	0	0
number of other artefacts with retouch/usewear that are backed	1	0	0	0	0
total number of other cores	0	0	0	0	0
% of other artefacts with retouch/usewear	50.0	16.7	0.0	0.0	0.0
χ^2	0.889	na	na	na	na
p(H_0)	0.346	na	na	na	na
reject H_0?	no	na	na	na	na

Four artefacts with ground patches first appear after 1700 BP at Cleft Rock Shelter, suggesting a change in the tasks carried out at the shelter. Table 6.17 summarises the details of the four pieces of rock with evidence of grinding. The four pieces are smaller than ground pieces found in open sites nearby (Bradshaw *et al.* 1996) and their fragmentary nature suggests there were part of larger grinding stones. They do not have any residues that suggest unambiguous evidence of food processing such as plant fibre, starch or blood. The lack food processing evidence suggests that the four pieces were probably not used for economic purposes, but the lack of this kind of evidence may be a result of their small size. The presence of red ochre on one specimen may reflect painting activity, such as for ceremonies, but could have resulted from haematite naturally occurring amongst the ironstone. The platy and friable quality of the rockshelter walls, and the absence of any extant Aboriginal painted art in Cleft Rock Shelter, suggests that if the grinding patches were used to prepare pigment it was probably for portable or body art.

Table 6.17 Summary of grinding evidence at Cleft Rock Shelter square 4A

SU = stratigraphic unit
EU = excavation unit

SU	EU	raw material	length mm	width mm	thickness mm	mass g	abraded area mm^2	residue
1	1	ironstone	55.3	48.6	20.7	83.4	811.2	none
2	2	ironstone	121.2	100.6	10.9	304.6	1891.3	none
2	3	ironstone	84.9	40.5	15.1	69.3	486.1	red ochre
2	3	bif	79.9	60.6	11.5	95.2	927.2	none

To summarise the analysis of artefacts with secondary working, backed artefacts and grinding stones at Cleft Rock Shelter, the similarly timed first appearance of backed artefacts and grinding evidence, coincident with a peak in artefact discard, suggests that after 1700 BP Cleft Rock Shelter was occupied more frequently and a greater variety of tasks were carried out. The absence of any significant changes in the numbers of artefacts with secondary working and technological changes relating to raw material availability at Cleft Rock Shelter suggests that the appearances of grinding technology and backed artefacts were not related to reorganisation of technology and subsistence, but to increases in occupation magnitude.

Magnetic susceptibility of sediments at Cleft Rock Shelter

To see whether the late Holocene appearance of new technologies was a result of a change in mobility (people spending more time at the site) or a regional change that is not related to the specific use of Cleft Rock Shelter, I measured the magnetic susceptibility of sediments from the three units. As for Marillana A, I expected long stays at Cleft Rock Shelter to be indicated by high magnetic susceptibility, caused by repeated firing of sediments in the same area in the shelter. Brief visits should be indicated by low magnetic susceptibility because sediments are not frequently fired and not frequently fired in the same place.

Figures 6.19-6.20 show the magnetic susceptibility and the coefficient of frequency dependency for samples of sediments from 13 of the 15 excavation units at Cleft Rock Shelter. These figures show that there is little difference in magnetic susceptibility of sediments over time at Cleft Rock Shelter. Table 6.18 shows that low frequency magnetic susceptibility and the coefficient of frequency dependency have weak correlations with other measures of occupation intensity except for soil organic matter and charcoal. Soil organic matter shows a moderate positive correlation with low frequency magnetic susceptibility. This may indicate that magnetic susceptibility measurements at Cleft Rock Shelter are more sensitive to processes of soil formation and organic material decay than changes in firing activity. On the other hand, the moderate positive correlation of magnetic susceptibility frequency dependency with charcoal confirms that the magnetic susceptibility of the sample analysed here is sensitive to the intensity of human or natural firing at Cleft Rock Shelter. These results indicate that magnetic susceptibility is an ambiguous indicator of

the intensity of firing and human occupation at Cleft Rock Shelter. A more comprehensive sampling strategy is needed to assess the usefulness of this technique in rockshelters like Cleft Rock Shelter.

Figure 6.19 Magnetic susceptibility of sediments samples from Cleft Rock Shelter square 4A

SU = stratigraphic unit

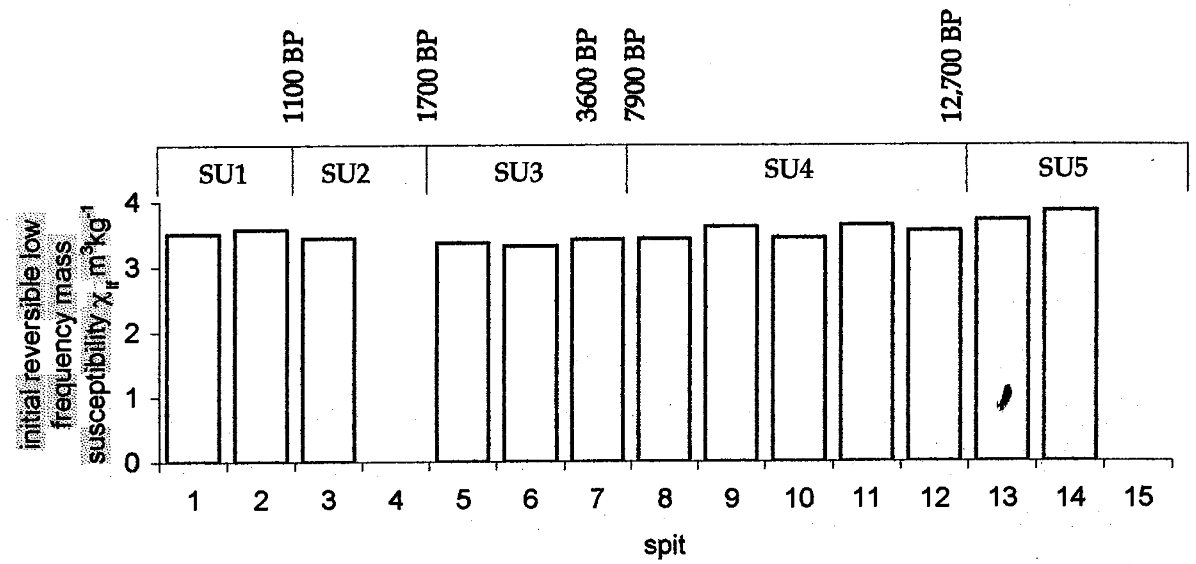


Figure 6.20 Coefficient of frequency dependency for sediment samples from Cleft Rock Shelter square 4A

SU = stratigraphic unit

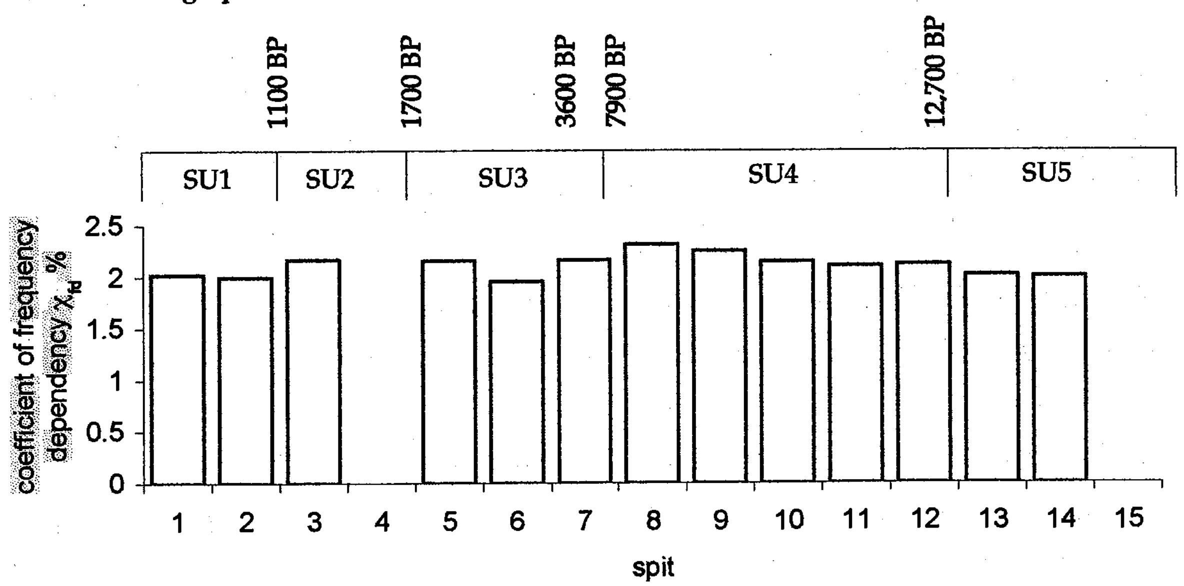


Table 6.18 Correlations between magnetic, cultural and other variables at Cleft Rock Shelter square 4A

χ_{lf}= **initial reversible low frequency mass susceptibility**
χ_{fd}= **coefficient of frequency dependency**
Bold type indicates $p(H_0) < 0.05$

	artefacts	soluble salts	charcoal	soil organic material
χ_{lf}	0.304	-0.393	-0.454	0.536
χ_{fd}	-0.283	-0.274	0.627	0.084

To summarise the magnetic susceptibility evidence, it indicates that the intensity of firing of sediments probably did not change throughout the history of occupation at Cleft Rock Shelter. If the magnetic susceptibility of the analysed samples are indicative of human firing patterns, the absence of change suggests that the duration of visits to Cleft Rock Shelter did not change over time. This suggests that peaks in the stone artefact discard are related to increases in the frequency, but not duration, of visits. The magnetic susceptibility evidence indicates that the first appearance of backed artefacts and grinding technology was probably not accompanied by significant changes in the duration of visits to the shelter.

Discussion

The evidence from Cleft Rock Shelter indicates that human occupation began before 12,700 BP. From the earliest occupation until recent times occupation of the shelter consisted of brief visits. Stone artefact evidence suggests that the highest frequency of visits to Cleft Rock Shelter occurred around 12,700 BP and a smaller peak in frequency of visits occurred at around 1700 BP. Non-lithic cultural evidence also suggests a peak in occupation around 1700 BP. After 7900 BP and again after 1700 BP there is an increase in the use of chert and a decrease in the use of siltstone for making stone artefacts. After 1700 BP the first backed artefacts and grinding fragments appear without any changes in technology or shelter use, suggesting that these artefacts represent the appearance or intensification of cultural systems rather than specific economic and technological changes. The timing of the grinding evidence is similar to P4507, suggesting that after 1700 BP grinding activity first appeared or intensified throughout the inland Pilbara.

7. Results and analysis: Milly's Cave

Milly's Cave is a rockshelter in Marra Mamba ironstone formation in the side of a small gorge that forms a tributary to Iowa Creek. (figures 7.1-7.2). In the gorge near Milly's Cave is a small spring that provides a constant supply of drinkable water. The shelter is 6.1 m wide and 4 m high at the drip line and 5.5 m deep (figure 7.3). It is the only site of the four examined here that contains evidence of LGM occupation.

Excavation

Lynda Strawbridge and her assistants excavated the shelter in 1990 and 1991. Local Aboriginal people visited the site while the excavation was in progress. In 1990 a one by one metre square (labelled 4A) was excavated in 13 spits (excavation units) to a depth of 70 cm (figure 7.4). In 1991 a second a one by one metre square (labelled 5A) was excavated in eight spits to a depth of about 25 cm. Excavation units were in arbitrary depths of about five centimetres.

The timing of occupation

To identify the period of time Milly's Cave represents and when changes in site formation processes occur, I relied mostly on Strawbridge's field descriptions. Three stratigraphic units are suggested by the section drawing made by Strawbridge in the field (figure 7.4). Data from my analysis of sediment attributes of Milly's Cave may not be reliable for identifying changes in the timing of occupation because sediment samples for only five of the 13 excavated spits were available for analysis, and these samples may not be representative of the changes in the excavated deposit (figure 7.4).

Strawbridge's section drawing indicates that the deposit from the surface to 27 cm below (surface to excavation unit five) is a homogenous deposit with a few rocks and an ashy lens in the east of the profile (figure 7.4). Strawbridge obtained a modern date (Wk 2187) from charcoal removed in situ from excavation unit four (20 cm below surface). I have identified this homogenous deposit as stratigraphic unit one.

Figure 7.1 Section and plan of Milly's Cave. Redrawn from Strawbridge's field drawings and measurements.

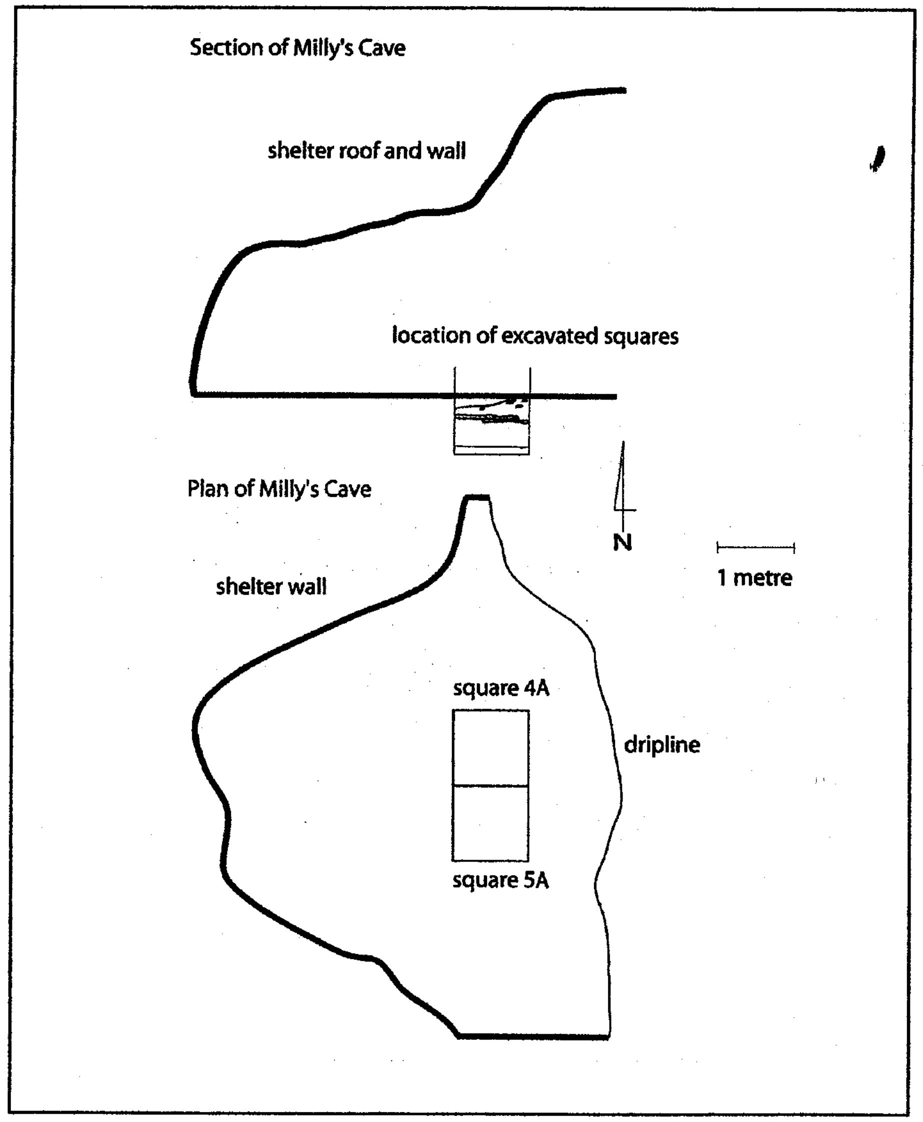


Figure 7.2 Photo taken by Strawbridge of the gully where Milly's Cave is located. The rockshelter is out of view to the lower right of the photo.

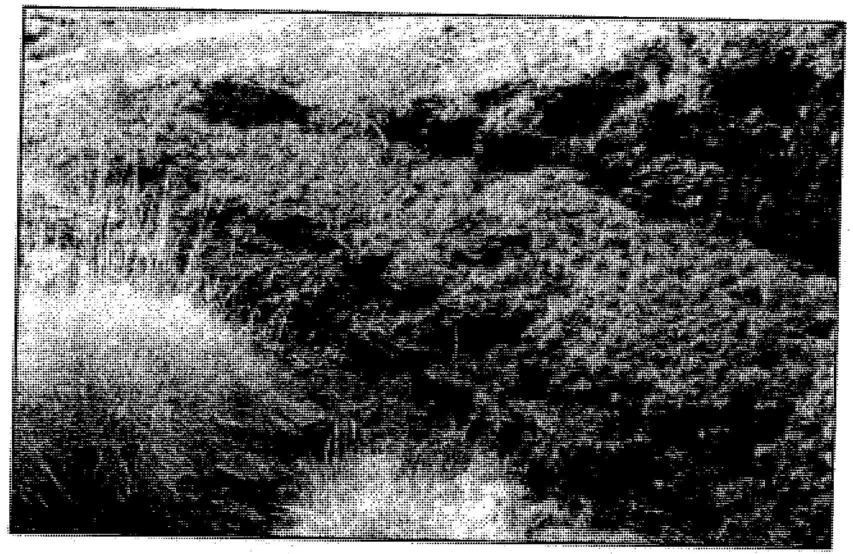


Figure 7.3 Photo taken by Strawbridge of the interior of Milly's Cave. The platy and friable nature of the Marra Mamba ironstone formation is visible in rockshelter wall the left of the photo and the pieces of roof-fall on the surface.

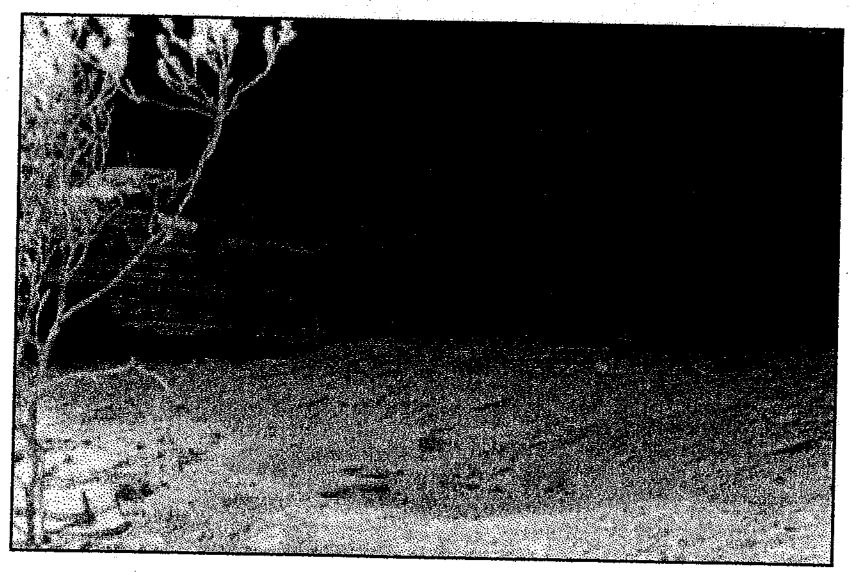
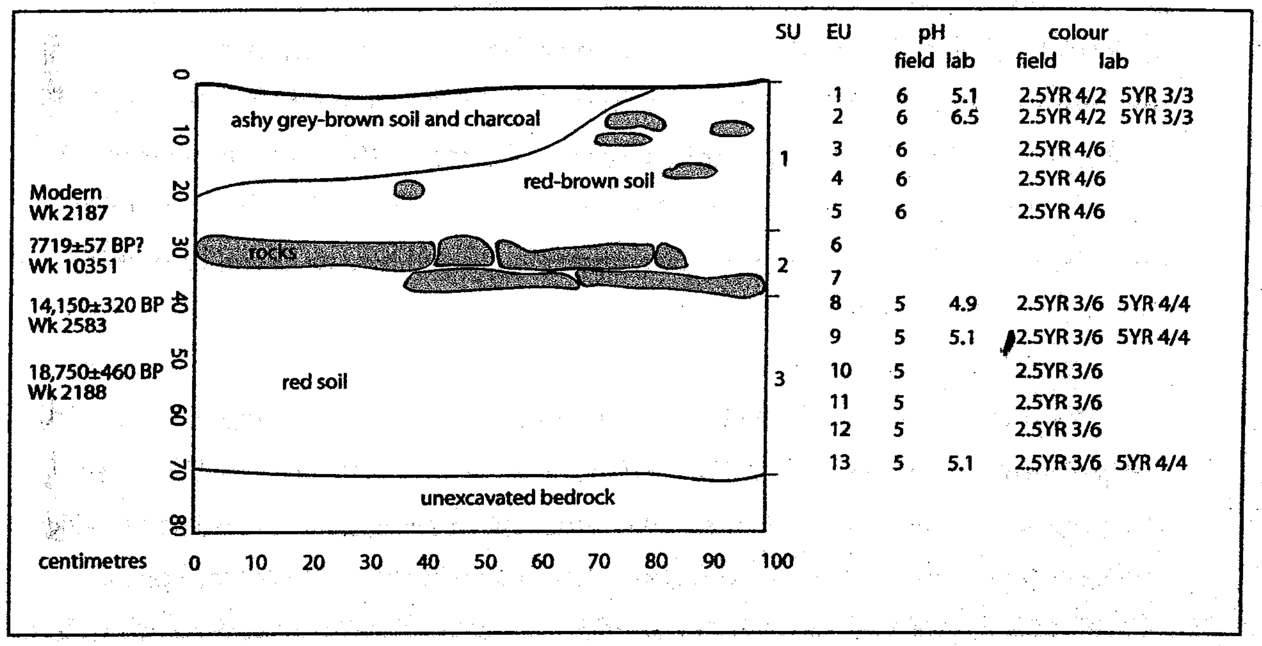


Figure 7.4 South section of excavated square 4A at Milly's Cave. Redrawn from Strawbridge's field drawings and measurements.

SU = stratigraphic unit
EU = excavation unit
field = measurement taken by Strawbridge during excavation
lab = analysis undertaken under laboratory conditions during 2001-2



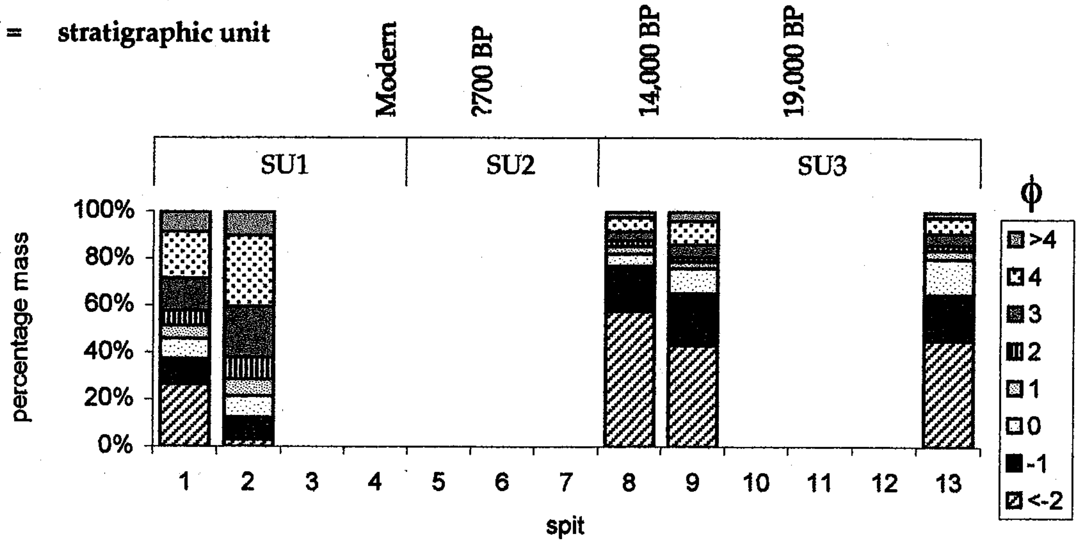
The lower boundary of stratigraphic unit one is defined by the surface of a roof fall layer 27-36 cm below the surface (excavation units five and six) that I have identified as stratigraphic unit two. Strawbridge's field notes from excavation units five and six record no artefacts or charcoal and 'a lot of rock' that was considered to indicate the base of the shelter. I obtained a date from charcoal taken out of bag of 3 mm sieve residue from excavation unit six of 719±57 BP (Wk 10351). This date should be rejected as too young because the roof fall layer at Marillana A is dated to 9000-13,000 BP suggesting that 9000 BP may be more reasonable estimate for the upper section of the roof fall at Milly's Cave, assuming that the two roof fall events are related. A similar date for the two roof fall events is suggested by the increased precipitation associated with the onset of the Australian summer monsoon at about 13,000 BP (Wyrwoll and Miller 2001). This increase in precipitation may have caused the roof falls at Marillana A and Milly's Cave because of increased amounts of water seeping through the rock formation and corroding and eroding the exposed banded ironstone. Unfortunately, with the evidence available I was not able to determine the causes of the roof falls at Milly's Cave and Marillana A.

A further reason to doubt the accuracy of the 719 BP date is the likelihood that the dated chracoal sample was not recovered in its original deposition context. Alan Hogg (University of Waikato Radiocarbon Dating Laboratory, pers comm. 2001) suggests that the 719 BP date may be anomalous because the small quantity (<1 g) of charcoal used to determine the date have migrated down through the deposit. Although the date is not out of sequence, it is treated here with doubt because of the possibility of migration and the poor correlation to the dates for the roof fall layer at Marillana A. This means that chronological resolution for stratigraphic units one and two is very low with the two units spanning from 14,000 BP to recent times.

Strawbridge describes a homogenous deposit from the base of the roof fall unit to base rock (36-70 cm below the surface, excavation units eight to 13), which I identify as stratigraphic unit three. My analysis of sediments included samples from three excavation units from this deposit and supports Strawbridge's description of the deposit as homogenous. The particle size analysis shows that the distributions of particle sizes in the two excavation units (eight and nine) near the top of stratigraphic unit three are similar to excavation unit 13 at the base of the deposit, supporting Strawbridge's description of stratigraphic unit three as homogenous (figures 7.4-7.5). Sediment colour is also similar between the three excavation units (figure 7.4).

Figure 7.5 Particle size distribution at Milly's Cave square 4A. Particle size fractions expressed as phi.

SU = stratigraphic unit



The timing of stratigraphic unit three is determined by two charcoal samples taken *in situ* by Strawbridge from excavation units eight and ten. The sample from excavation unit eight was dated to 14,150±320 BP (Wk 2583) and the sample from excavation unit ten to 18,750±460 BP (Wk 2188). These dates suggest that unit three was deposited around the time of the Last Glacial Maximum and cultural material from this stratigraphic unit will reflect human responses to this period of increased aridity. I was not able to obtain dates for the base of the sequence because no charcoal was available.

CHANGES IN THE INTENSITY AND TYPE OF OCCUPATION

Organic material and soluble salt concentration

I analysed rates of deposition of soil organic material and charcoal and changes in the concentration of soluble salts at Milly's Cave as possible measures of changes in the intensity of human occupation. I did not find any sedimentary organic matter, such as faunal and floral remains, in the collection or any record of this material in Strawbridge's field notes. Figure 7.6 shows that charcoal is most abundant in stratigraphic unit one with very small amounts in stratigraphic unit three. The mass of charcoal from excavation units eight and ten is lower than the actual values because unknown amounts of charcoal were removed for dating prior to my determination of charcoal mass.

Figure 7.6 Charcoal density at Milly's Cave square 4A

SU= stratigraphic unit

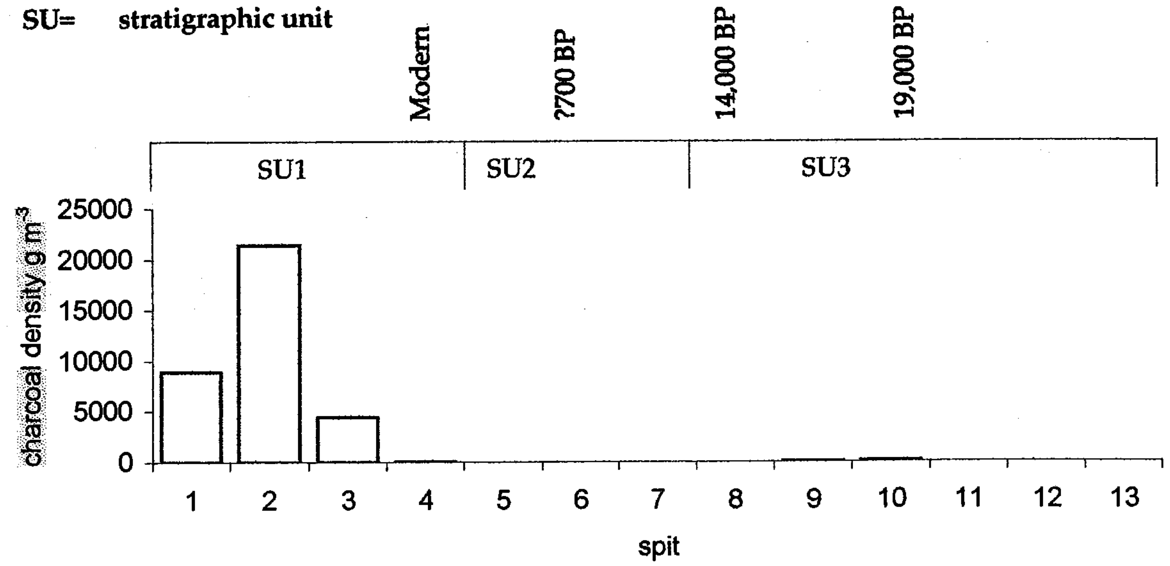
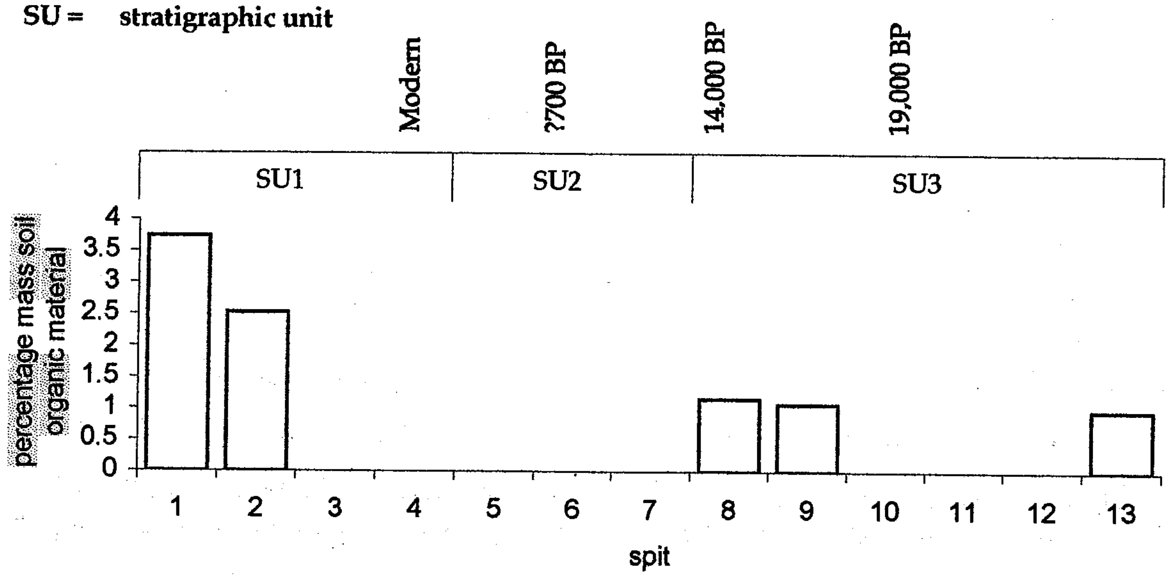


Figure 7.7 shows the distribution of soil organic material at Milly's Cave square 4A. The gradual decline from the surface to the lower spits, combined with the sparse sample, suggests that processes of natural decay best explain the distribution of soil organic material at Milly's Cave.

Figure 7.7 Soil organic material distribution at Milly's Cave square 4A

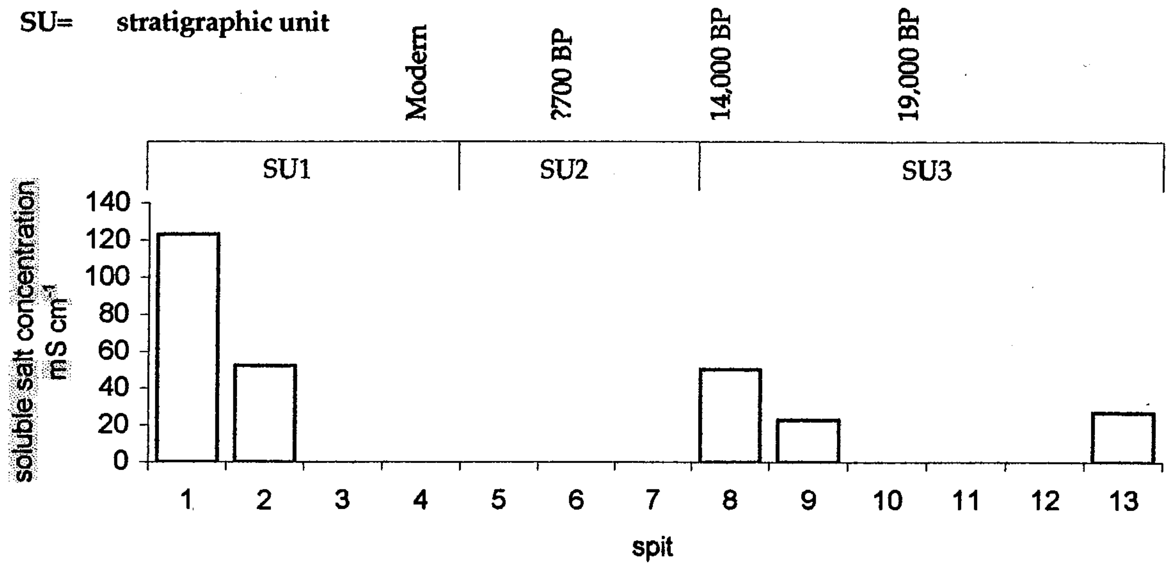
SU = stratigraphic unit



Soluble salt concentration at Milly's Cave reflects the charcoal distribution, but this may result from sampling rather than a real correlation. Figure 7.8 shows the soluble salt concentration for the excavation units for which sediment samples were available. Caution should be advised in the interpretation of the soluble salt, organic material and charcoal distributions at Milly's Cave because of the limited samples available for analysis. If samples from all excavation units were available, then the distribution of soluble salt, organic material and charcoal might appear as part of a gradual decline rather than one or two peaks.

Figure 7.8 Soluble salt concentration at Milly's Cave square 4A

SU= stratigraphic unit

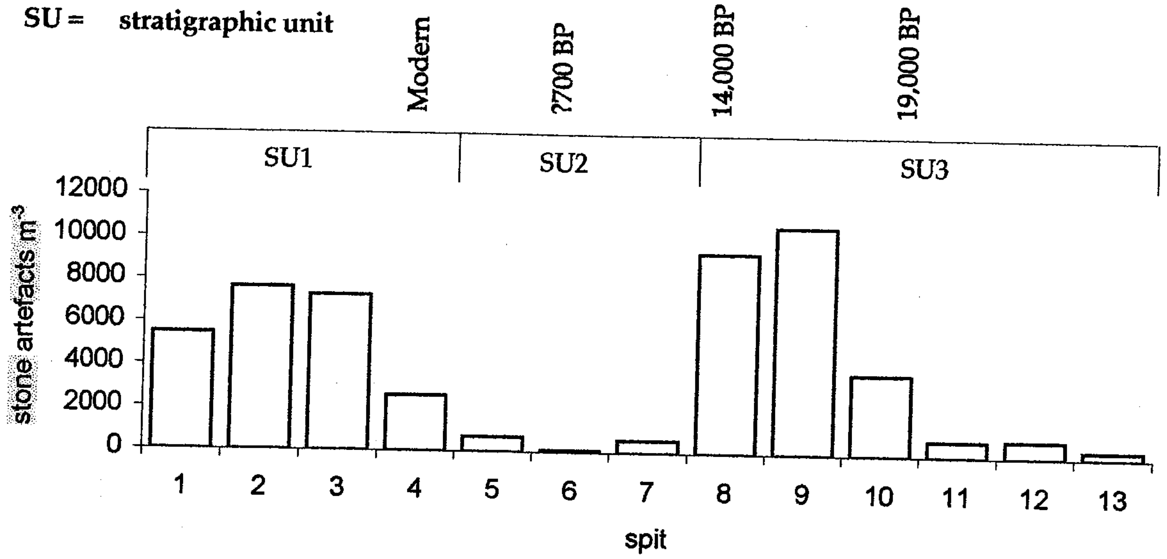


Stone artefacts

Stone artefacts are the main source of information on human occupation at Milly's Cave because, unlike the sedimentary evidence, samples are available from all thirteen excavation units. Figure 7.9 shows the number of artefacts per cubic metre of sediment per spit. The majority of stone artefacts are discarded in unit three between 14,000 BP and 19,000 BP suggesting that this was a period of intensive occupation at Milly's Cave (n = 737, 49.2% of the total assemblage, 14.7 artefacts per hundred years). A smaller peak in stone artefact discard occurs after 200 BP (n = 534, 36.1% of the total assemblage, 267 artefacts per hundred years). Although this second peak is smaller, the rate of artefact discard is actually higher than the LGM peak, indicating that this is the time of the most abundant stone artefact discard and possibly the most intensive occupation of the site. Between 14,000 BP and 200 BP only 127 artefacts were recovered (8.4% of the total assemblage, 0.9 artefacts per hundred years). The small number of artefacts discarded before 19,000 BP (n = 191, 6.7% of the total assemblage) suggest that Milly's Cave was not intensively occupied at this time.

Figure 7.9 Stone artefact discard at Milly's Cave square 4A (n = 1497)

SU = stratigraphic unit



The roof fall period (stratigraphic unit two) may have included a period of erosion that destroyed deposits associated with the roof fall layer, but the absence of a lag deposit of artefacts immediately beneath the roof fall layer (excavation units six and seven) indicates that the roof fall layer was probably not accompanied by high rates of erosion. This suggests that changes in artefact discard rates are best explained by changes in human behaviour rather and changes in site formation processes other than erosion.

I analysed the stone artefacts from Milly's Cave to see whether changes in post-depositional processes, artefact manufacture and site function were likely causes of the changes in artefact density.

Post-depositional change

Post-depositional change may explain increases in artefact discard because breakage increases the number of artefacts per unit of volume. To see whether there are any changes in post-depositional processes that may explain the peaks in discard I compared the degree of breakage between units using the Sullivan and Rozen (1985) typology. Table 7.1 shows the number of each debitage type for each stratigraphic unit in square 4A.

Table 7.1 Debitage analysis of stone artefacts from Milly's Cave square 4A

SU = stratigraphic unit
n = number of artefacts
$\%_1$ = percent of total artefacts recovered from the site
$\%_2$ = percent of total artefacts recovered from stratigraphic unit

SU	total artefacts		complete flake		broken flake (long)		broken flake (trans)		flake fragment		angular piece	
	n	$\%_1$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$
1	547	36.5	25	4.6	3	0.5	6	1.1	146	26.7	367	67.1
2	113	7.5	9	8.0	0	0.0	1	0.9	26	23.0	77	68.1
3	837	55.9	86	10.3	1	0.1	9	1.1	284	33.9	457	54.6

The percentages in table 7.1 show that the proportions of debitage types change very little over time at Milly's Cave. Table 7.2 shows that differences in numbers of debitage types between the three stratigraphic units are not significant.

Table 7.2 Chi-square tests on differences in the numbers of each debitage type between stratigraphic units at Milly's Cave square 4A

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_o)$= probability that the null hypothesis (that there is no difference) is true

SU	χ^2	df	$p(H_0)$	reject H_0?
1:2	0.809	3	0.847	no
2:3	3.786	3	0.285	no

I identified a conjoin between two angular fragments of banded ironstone formation in the northeast quadrant of excavation unit eight. The close proximity of these pieces to each other suggests that post-depositional disturbance was minimal and stratigraphic integrity is high at excavation unit eight. These debitage and conjoin data indicate that the degree of post-depositional change is similar between the three stratigraphic units and that the artefact discard pattern at Milly's Cave cannot be explained by a change in post-depositional processes.

Artefact manufacture

Raw materials

The failure of changes in site formation and post-depositional processes to account for the changes in artefact discard suggests that changes in the production of artefacts might explain the artefact discard pattern at Milly's Cave. Changes in the choice of raw materials can influence discard rate because different raw materials have different fracturing characteristics that can result in the production of different amount of artefacts using the same techniques. Table 7.3 shows the number and percentage of the main raw material types in the three units at Milly's Cave.

Table 7.3 Raw material of stone artefacts at Milly's Cave square 4A

SU = stratigraphic unit
n = number of artefacts
$\%_1$ = percent of total artefacts recovered from the site
$\%_2$ = percent of total artefacts recovered from stratigraphic unit

SU	total artefacts		bif		chert		ironstone		quartz		siltstone		others	
	n	$\%_1$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$	n	$\%_2$
1	547	36.5	282	51.6	115	21.0	125	22.9	2	0.4	12	2.2	11	2.0
2	113	7.5	54	47.8	12	10.6	30	26.5	0	0.0	6	5.3	11	9.7
3	837	55.9	304	36.3	477	57.0	31	3.7	11	1.3	4	0.5	10	1.2

Tables 7.4 to 7.6 show that from stratigraphic unit three to unit two, after about 14,000 BP, there are significant increases in the numbers of artefacts made from chert, ironstone and bif. From stratigraphic unit two to unit one, there is a significant reduction in the numbers of chert artefacts (table 7.4), but no change in abundance of ironstone and bif (tables 7.5-7.6).

Table 7.4 Chi-square tests on differences in the numbers of chert artefacts between stratigraphic units at Milly's Cave square 4A

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true
ϕ= Phi coefficient (direction of association)
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

SU	χ^2	df	$p(H_0)$	reject H_0?	ϕ	C_{adj}
1:2	6.524	1	0.01	yes	0.099	0.093
2:3	85.701	1	2.09×10^{-20}	yes	-0.300	0.407

Table 7.5 Chi-square tests on differences in the numbers of ironstone artefacts between stratigraphic units at Milly's Cave square 4A

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true
ϕ= Phi coefficient (direction of association)
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

SU	χ^2	df	$p(H_0)$	reject H_0?	ϕ	C_{adj}
1:2	0.712	1	0.399	no	na	na
2:3	86.472	1	1.42×10^{-20}	yes	0.302	0.408

Table 7.6 Chi-square tests on differences in the numbers of bif artefacts between stratigraphic units at Milly's Cave square 4A

SU= stratigraphic unit
χ^2= chi-square
df= degrees of freedom
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true
ϕ= Phi coefficient (direction of association)
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

SU	χ^2	df	$p(H_0)$	reject H_0?	ϕ	C_{adj}
1:2	0.532	1	0.466	no	na	na
2:3	5.575	1	0.018	yes	0.077	0.079

The changes in raw material abundances may be related to the discard peaks in stratigraphic units three and one. Ironstone and bif are heterogenous, anisotropic and medium grained rocks. The heterogenous fabric of ironstone and bif and their tendency to fracture along planes (that may not be visible on the outside of the rock) makes fracturing unpredictable, resulting in large amounts of shatter and broken pieces when making artefacts from ironstone and bif. Chert is a homogenous and fine-grained siliceous rock that fractures conchoidally. This means that artefacts can be produced reliably and predictably from chert with little shatter from pieces that break during manufacture. If raw material changes are the causes of changes in artefact discard then increases in ironstone and bif should be expected to coincide with peaks in artefact discard because they produce more waste during flaking.

The highest peak in artefact discard per unit of sediment volume occurs in stratigraphic unit three, where chert is the most abundant raw material (57%, n

= 477), and the decline in artefact discard from stratigraphic unit three to two is accompanied by a reduction in the abundance of chert (tables 7.3-7.4). The increase in artefact discard in stratigraphic unit one coincides with an increase in chert artefacts. These changes in raw materials are opposite to that expected if changes in raw materials were responsible for the increases in artefact density. An increase in ironstone and bif or similar raw materials may explain a peak in artefact discard, but at Milly's Cave there is an increase in chert. This suggests that the changes in raw material were not the cause of the increased artefact discard during the LGM or the late Holocene.

Technological variables

To discover whether changes in the technological processes indicative of changes in raw material conservation strategies influenced the changes in discard rate I looked for changes in the technological and metric variables of stone artefacts. Tables 7.7-7.9 show that there is no convincing evidence for changes in the technology of artefact manufacture at Milly's Cave. Tables 7.10-7.12 and figures 7.10-7.18 show that although the size of chert artefacts does not change, the size of artefacts made from bif and other raw materials increases after 14,000 BP and again in the late Holocene. This increase in size probably does not indicate a change in technology because it is not accompanied by other indicators of less efficient production, such as increased dorsal cortex, increased dorsal flake scars and increased cortical platforms. To summarise, there are no changes in artefact manufacturing techniques that explain the differences in discard rates between the three units.

Table 7.7 Summary of technological analysis of chert flakes from Milly's Cave square 4A

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit									
		1		2		3					
	years BP	Modern-?700		?700-14,000		14,000-19,000					
	number of chert complete flakes	17		3		55					
	% of all flakes in the unit that are chert	68		33.3		64.0					
								significant change in variable?			
		n	%	n	%	n	%	reject H_0?	C_{adj}	when?	direction?
termination	feather	14	82.4	2	66.7	51	92.7	no	na	na	na
platform surface	flat	11	64.7	1	33.3	33	60.0	no	na	na	na
	facetted	6	35.3	2	66.7	14	25.5	no	na	na	na
	cortical	0	0.0	0	0.0	8	14.5	na	na	na	na
platform type	wide	10	58.8	3	100.0	45	81.8	no	na	na	na
	focalised	3	17.6	0	0.0	4	7.3	na	na	na	na
	gull	4	23.5	0	0.0	6	10.9	na	na	na	na
overhang removal	flakes with overhang removal	11	64.7	1	33.3	31	56.4	no	na	na	na
reduction level	flakes with >1 dorsal flake scar	5	29.4	2	66.7	8	14.5	yes	0.212	SU2:3 14,000 BP	decrease
	flakes with distal and lateral flake scars	2	11.8	0	0.0	2	3.6	na	na	na	na
	flakes with <10 cortex	7	41.2	2	66.7	21	38.2	no	na	na	na
	flakes with 10-50 cortex	4	23.5	1	33.3	19	34.5	no	na	na	na
	flakes with >50 cortex	0	0.0	0	0.0	0	0.0	na	na	na	na

Table 7.8 Summary of technological analysis of bif flakes from Milly's Cave square 4A

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit 1		2		3					
	years BP	Modern-?700		?700-14,000		14,000-19,000					
	number of bif complete flakes	7		5		26					
	% of all flakes that are bif	28		55.6		30.2		significant change in variable?			
		n	%	n	%	n	%	reject H_0?	C_{adj}	when?	direction?
termination	feather	5	71.4	5	100	20	76.9	no	na	na	na
platform surface	flat	3	42.9	1	20	14	53.8	no	na	na	na
	facetted	4	57.1	2	40	8	30.8	no	na	na	na
	cortical	0	0.0	2	40	4	15.4	no	na	na	na
platform type	wide	3	42.9	3	60	20	76.9	no	na	na	na
	focalised	4	57.1	2	40	6	23.1	no	na	na	na
	gull	0	0.0	0	0	0	0.0	na	na	na	na
overhang removal	flakes with overhang removal	4	57.1	2	40	13	50.0	no	na	na	na
reduction level	flakes with >1 dorsal flake scar	1	14.3	2	40	7	26.9	no	na	na	na
	flakes with distal and lateral flake scars	0	0.0	0	0	0	0.0	na	na	na	na
	flakes with <10 cortex	2	28.6	2	40	7	26.9	no	na	na	na
	flakes with 10-50 cortex	5	71.4	3	60	19	73.1	no	na	na	na
	flakes with >50 cortex	0	0.0	0	0	0	0.0	na	na	na	na

Table 7.9 Summary of technological analysis of flakes made from raw materials other than chert and bif from Milly's Cave square 4A

n= number of artefacts
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by chi-square tests
C_{adj}= Pearson's contingency coefficient adjusted (strength of association)

		stratigraphic unit 1		2		3					
	years BP	Modern-?700		?700-14,000		14,000-19,000					
	number of other complete flakes	1		1		6					
	% of all flakes that are other	4		11.1		7.0		significant change in variable?			
		n	%	n	%	n	%	reject Ho?	strength	when?	direction?
termination	feather	1	100	0	0	4	66.7	na	na	na	na
platform surface	flat	1	100	1	100	3	50.0	na	na	na	na
	facetted	0	0	0	0	2	33.3	na	na	na	na
	cortical	0	0	0	0	1	16.7	na	na	na	na
platform type	wide	1	100	1	100	4	66.7	na	na	na	na
	focalised	0	0	0	0	1	16.7	na	na	na	na
	gull	0	0	0	0	1	16.7	na	na	na	na
overhang removal	flakes with overhang removal	0	0	0	0	2	33.3	na	na	na	na
reduction level	flakes with >1 dorsal flake scar	0	0	0	0	2	33.3	na	na	na	na
	flakes with distal and lateral flake scars	0	0	0	0	0	0.0	na	na	na	na
	flakes with <10 cortex	0	0	1	100	2	33.3	na	na	na	na
	flakes with 10-50% cortex	1	100	0	0	5	83.3	na	na	na	na
	flakes with >50 cortex	0	0	0	0	0	0.0	no	na	na	na

Table 7.10 Summary of metric analysis of chert flakes from Milly's Cave square 4A

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t-tests

	stratigraphic unit	1	2	3
	time period	Modern-?700	?700-14,000	14,000-19,000 BP
	total number of chert artefacts	115	12	477
	total number of flakes	17	3	55
mass of total artefacts	mean (g)	1.74	1.90	0.73
	significant change? t	-0.148	0.843	na
	$p(H_0)$	0.883	0.399	na
	reject H_0?	no	no	na
flake length	mean (mm)	17.11	14.33	10.42
	significant change? t	-0.041	1.191	na
	$p(H_0)$	0.968	0.239	na
	reject H_0?	no	no	na
flake width	mean (mm)	16.04	11.90	10.86
	significant change? t	0.869	-0.223	na
	$p(H_0)$	0.396	0.824	na
	reject H_0?	no	no	na
flake thickness	mean (mm)	3.25	3.70	2.49
	significant change? t	-0.400	0.935	na
	$p(H_0)$	0.694	0.354	na
	reject H_0?	no	no	na
flake mass	mean (g)	2.60	1.43	0.77
	significant change? t	0.391	0.365	na
	$p(H_0)$	0.700	0.717	na
	reject H_0?	no	no	na
flake platform width	mean (mm)	11.83	7.40	7.78
	significant change? t	0.573	0.190	na
	$p(H_0)$	0.574	0.850	na
	reject H_0?	no	no	na

Figure 7.10 Frequency distribution of chert flake lengths in unit one of Milly's Cave square 4A

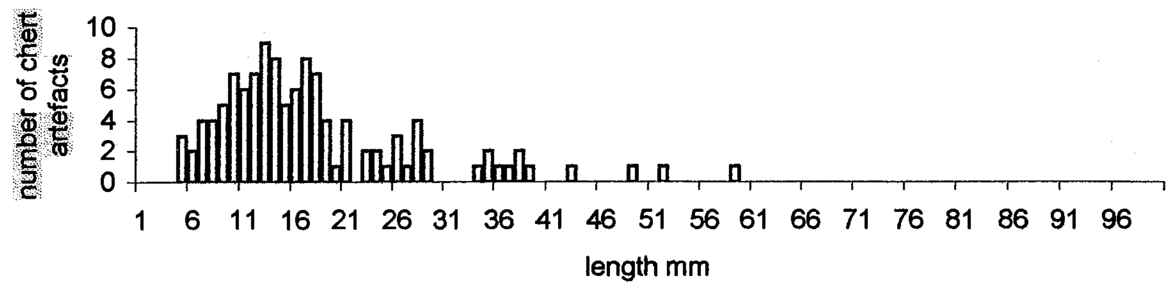


Figure 7.11 Frequency distribution of chert flake lengths in unit two of Milly's Cave square 4A

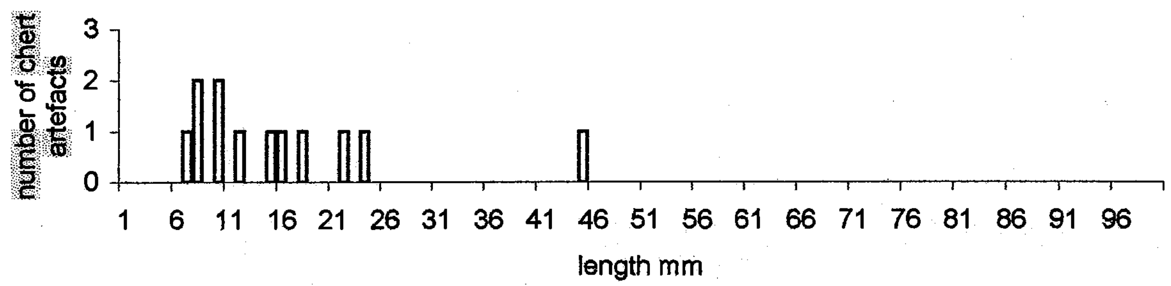


Figure 7.12 Frequency distribution of chert flake lengths in unit three of Milly's Cave square 4A

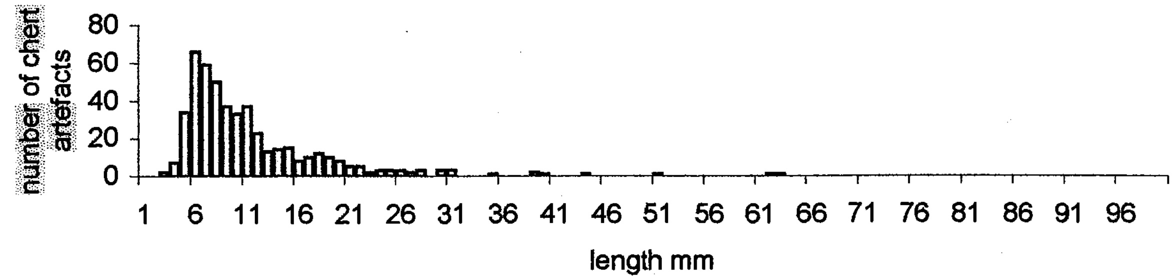


Table 7.11 Summary of metric analysis of bif flakes from Milly's Cave square 4A

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)

$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t-tests

	stratigraphic unit	1	2	3
	time period	Modern-?700	?700-14,000	14,000-19,000 BP
	total number of bif artefacts	282	54	317
	total number of bif flakes	7	5	26
mass of total artefacts	mean (g)	16.7	14.7	10.5
significant change?	t	2.596	4.307	na
	$p(H_0)$	0.010	2.12×10^{-5}	na
	reject H_0?	yes - increase	yes - increase	na
flake length	mean (mm)	19.1	17.5	12.9
significant change?	t	0.574	1.407	na
	$p(H_0)$	0.579	0.170	na
	reject H_0?	no	no	na
flake width	mean (mm)	13.6	11.3	12.0
significant change?	t	1.013	-0.079	na
	$p(H_0)$	0.335	0.938	na
	reject H_0?	no	no	na
flake thickness	mean (mm)	3.4	2.6	2.9
significant change?	t	1.666	0.169	na
	$p(H_0)$	0.127	0.867	na
	reject H_0?	no	no	na
flake mass	mean (g)	1.0	0.6	0.9
significant change?	t	1.234	0.430	na
	$p(H_0)$	0.246	0.670	na
	reject H_0?	no	no	na
flake platform width	mean (mm)	8.3	7.1	7.6
significant change?	t	0.396	-0.064	na
	$p(H_0)$	0.701	0.949	na
	reject H_0?	no	no	na

Figure 7.13 Frequency distribution of bif flake lengths in unit one of Milly's Cave square 4A

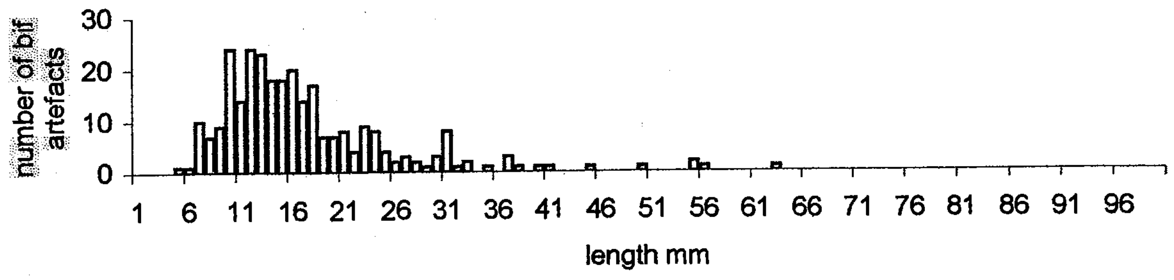


Figure 7.14 Frequency distribution of bif flake lengths in unit two of Milly's Cave square 4A

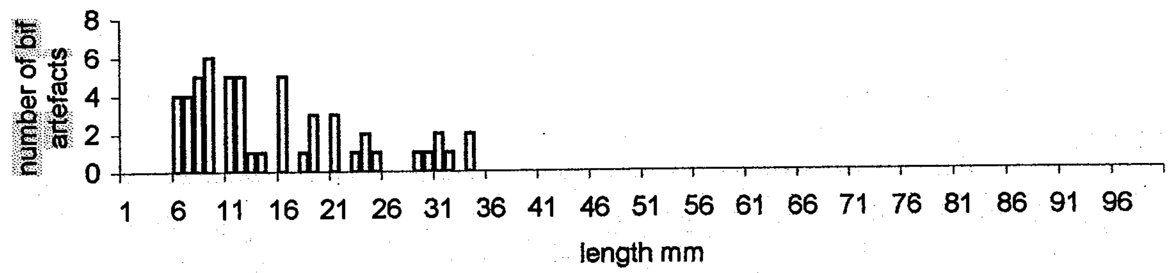


Figure 7.15 Frequency distribution of bif flake lengths in unit three of Milly's Cave square 4A

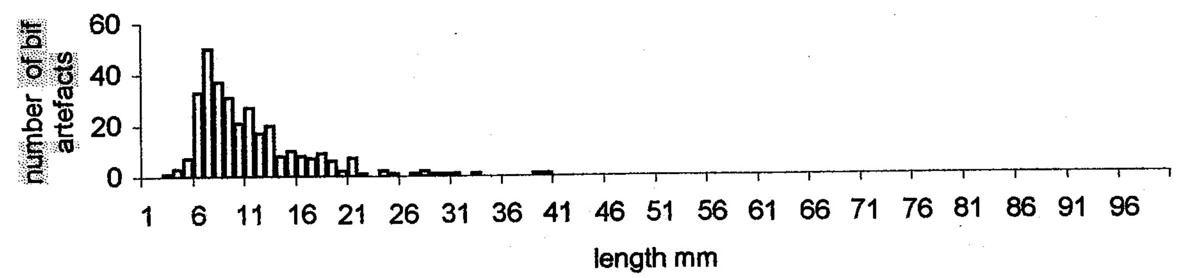


Table 7.12 Summary of metric analysis of flakes made from raw materials other than bif or chert from Milly's Cave square 4A

t= t-statistic calculated from t-test for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true, calculated by t-tests

		1	2	3
stratigraphic unit		1	2	3
time period		Modern-?700	?700-14,000	14,000-19,000 BP
total number of other artefacts		153	47	73
total number of other flakes		1	1	6
mass of total artefacts	mean (g)	3.7	2.0	0.6
significant change?	t	2.441	3.624	na
	$p(H_0)$	0.016	0.0004	na
	reject H_0?	yes - increase	yes - increase	na

Figure 7.16 Frequency distribution of flake lengths in unit one of flakes made from raw materials other than bif or chert Milly's Cave square 4A

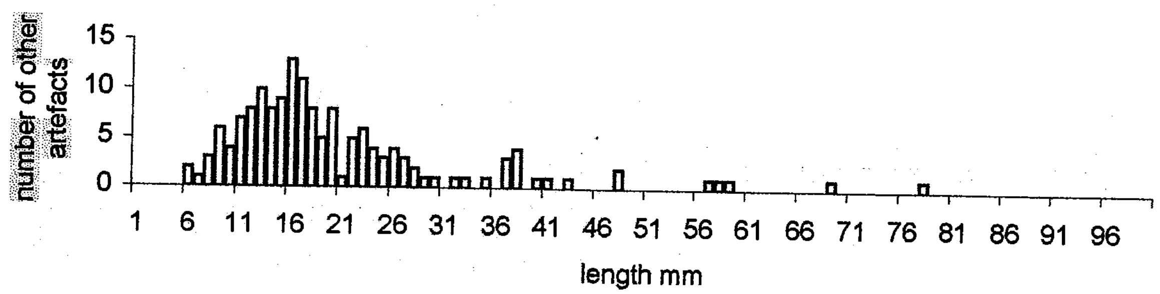


Figure 7.17 Frequency distribution of flake lengths in unit two of flakes made from raw materials other than bif or chert Milly's Cave square 4A

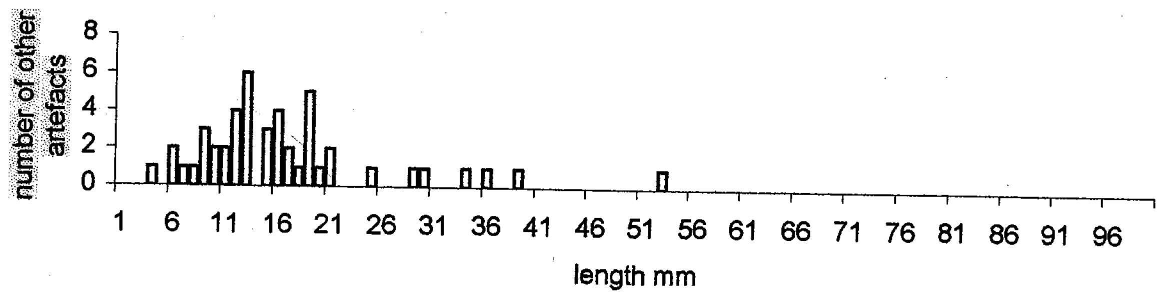
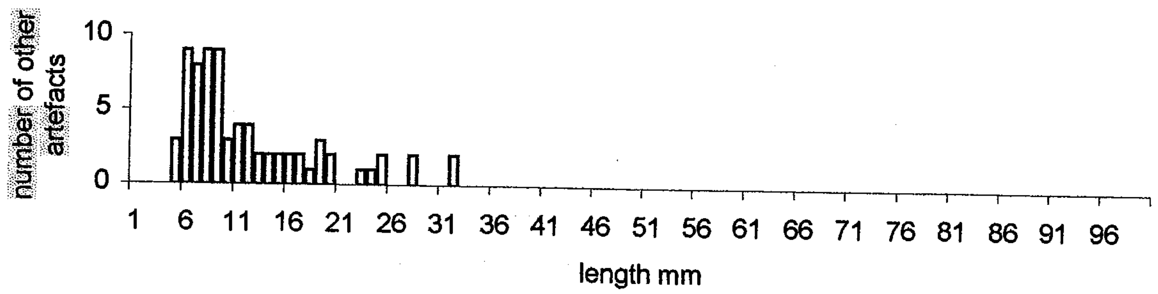


Figure 7.18 Frequency distribution of flake lengths in unit three of flakes made from raw materials other than bif or chert Milly's Cave square 4A



Change in the function of the site

Analysis of artefacts with secondary working suggests that the function of Milly's Cave and the tasks carried out there did not change over time. Tables 7.13-7.16 show that there are low numbers of artefacts with secondary working in each of the three stratigraphic units. There is a significant increase in chert worked artefacts after 14,000 BP, but the sample is very small (2 worked out of 12 chert artefacts) so this may not represent long-term change in the use of the site (table 7.14).

Table 7.13 Summary of all artefacts with evidence of secondary working and cores from Milly's Cave square 4A

χ^2= chi-square
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3
years BP	Modern-?700	?700-14,000	14,000-19,000
total number of artefacts	547	113	837
total number of artefacts with retouch/usewear	17	2	20
number of artefacts with retouch/usewear that are backed	0	0	0
total number of cores	1	0	2
% of artefacts with retouch/usewear	3.1	1.8	2.4
χ^2	0.600	0.169	na
$p(H_0)$	0.439	0.681	na
reject H_0?	no	no	na

Table 7.14 Summary of chert artefacts with evidence of secondary working and cores from Milly's Cave square 4A

χ^2= chi-square
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3
years BP	Modern-?700	?700-14,000	14,000-19,000
total number of chert artefacts	115	12	477
total number of chert artefacts with retouch/usewear	11	2	15
number of chert artefacts with retouch/usewear that are backed	0	0	0
total number of chert cores	0	0	1
% of chert artefacts with retouch/usewear	9.6	16.7	3.1
χ^2	0.596	6.378	na
$p(H_0)$	0.440	0.012	na
reject H_0?	no	yes - increase	na

Table 7.15 Summary of bif artefacts with evidence of secondary working and cores from Milly's Cave square 4A

χ^2= chi-square
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3
years BP	Modern-?700	?700-14,000	14,000-19,000
total number of bif artefacts	282	54	304
total number of bif artefacts with retouch/usewear	5	0	3
number of bif artefacts with retouch/usewear that are backed	0	0	0
total number of bif cores	1	0	0
% of bif artefacts with retouch/usewear	1.7	0	0.9
χ^2	0.971	0.537	na
$p(H_0)$	0.324	0.463	na
reject H_0?	no	no	na

Table 7.16 Summary of artefacts made from raw materials other than chert and bif with evidence of secondary working and cores from Milly's Cave square 4A

χ^2= chi-square
$p(H_0)$= probability that the null hypothesis (that there is no difference) is true

stratigraphic unit	1	2	3
years BP	Modern-?700	?700-14,000	14,000-19,000
		1	
total number of other artefacts	153	47	73
total number of other artefacts with retouch/usewear	1	0	2
number of other artefacts with retouch/usewear that are backed	0	0	0
total number of other cores	0	0	1
% of other artefacts with retouch/usewear	0.7	0.0	2.7
chi-square	0.309	na	na
p(H0)	0.578	na	na
significant change in numbers of artefacts with retouch/usewear?	no	na	na

The uniformly low proportions of worked artefacts and cores suggest that Milly's Cave was a site of brief visits and small-scale opportunistic stone working events throughout the history of its occupation. Reduced mobility and longer stays at the site may have involved extended reduction of tools and cores, producing an assemblage with a higher proportion of worked artefacts and cores, but this is not evident in the secondary working evidence. At Milly's Cave the relative abundances of bif and chert, representing local and exotic raw materials, provide an alternative method to observing changes in land-use patterns.

Evidence from similar sites in Australia occupied during the LGM, such as Colless and Louis Creek Caves (Hiscock 1988:225-6) and Fern Cave (Lamb

1996), indicates that a reduction in territorial range was a response by people to the increased aridity of the LGM. I analysed changes in exotic and local raw materials in stratigraphic unit three of Milly's Cave to see whether there were any changes in the size of the territory of stone artefact raw material procurement in response to the environmental changes of the LGM. The diversity of stone available in the Pilbara makes identifying local and exotic stone difficult (Veth 1984, Brown 1987:5-6) and of the four sites examined here Milly's Cave was the only one that I was able to discern local and exotic artefactual stone.

At Milly's Cave I was able to identify two types of chert that could be distinguished as local and exotic. Local chert forms in the banded ironstone formation that consists of thin layers of chert and ironstone and is immediately available from the rockshelter walls and roof and the surrounding Marra Mamba formation. Local chert (known as bif-origin chert) is highly silicified banded ironstone formation, with similar mechanical properties to other forms of chert, but visually distinctive because of its thin dark layering. Exotic chert is distinctive because it is not banded and comes in a variety of colours not found in bif-origin chert. Table 7.17 shows that during the LGM occupation period there is a significantly higher number of artefacts (χ^2= 27.97, df= 1, $p(H_0)$= 1.22×10^{-7}) made from locally available bif-origin chert compared to the late Holocene occupation. The focus on locally available raw materials to the exclusion of exotic raw materials during the LGM is suggests a reduced scale of territorial range compared to Holocene occupation.

Table 7.17 Local and exotic chert at Milly's Cave square 4A

stratigraphic unit	1	2	3
total number of artefacts	547	113	837
total number of chert artefacts in unit	115	12	477
% of chert artefacts in unit	21.0	10.6	56.9
total number of bif-origin chert artefacts in unit	5	0	131
% of total chert artefacts that are bif-origin chert	4.3	0	27.4

If the risk of acquiring exotic raw materials increased as they decreased in abundance in the assemblage, then artefacts made from exotic raw materials should be smaller because of attempts to conserve the material through more extensive reduction. Table 7.18 shows that there are no significant differences in the masses of flakes of different raw materials during the LGM occupation. This indicates that while local cherts were more frequently exploited, all raw materials were reduced to a similar size. Artefacts made from exotic raw materials are not smaller than local raw material in the LGM unit, indicating that there was no change in the demand or availability of raw materials. The absence of differences in artefact size between raw materials suggests that distance from source was the most important raw material procurement variable that significantly changed during the LGM at Milly's Cave. The similar flaking qualities of local and exotic cherts and the similar sizes of artefacts made from these raw materials during the LGM indicate that risk was probably not a significant variable in the procurement of raw materials at Milly's Cave.

Table 7.18 Comparison of flake mass statistics for local, exotic and other cherts in unit three of Milly's Cave square 4A

Significance of difference in means calculated from t-tests for two independent samples (data transformed to their base 10 logarithms to approximate normal distribution required for t-test calculation)

	chert	bif-chert	bif	others
total number of artefacts	40	15	26	5
% of all flakes in unit 3	47.1	17.6	29.4	5.9
mean mass (g)	0.70	0.98	0.80	0.59
max mass (g)	5.89	3.82	3.71	1.58
min mass (g)	0.01	0.01	0.01	0.01
range mass (g)	5.88	3.81	3.7	1.57
standard deviation mass (g)	1.33	1.40	1.01	0.63
significant difference in means between raw materials?	no	no	no	no

To summarise, the function of Milly's Cave as the location of brief visits appears to have been constant throughout the history of its occupation. There is no evidence, such as an increase in worked artefacts, cores or particular types of artefacts, which suggest a change in the type of activities carried out at the site. The only evidence for change occurs during the LGM when an increased use of local cherts suggests that the occupants of the site at this time acquired their raw materials from artefact manufacture from a small territorial range than occupants at later times.

Discussion

Analysis of cultural materials indicates that Milly's Cave was most intensively occupied during the LGM and then again in recent times. The increase in occupation intensity during the LGM period probably resulted from increase in the frequency of visits rather than their duration. Increased frequency of visits to Milly's Cave was accompanied by a reduction in territorial area during the LGM compared to later periods. This LGM reduction in territorial area may be evidence of a narrowing of resource catchments to a small but well-watered area including the spring in the gorge near Milly's Cave. The proximity of Milly's Cave to the high relief north-eastern scarp of the Hamersley Plateau may have made it an attractive location during the LGM. The scarp drains the plateau into the Fortescue River resulting in increased concentrations of water and other resources along the scarp compared to the Pilbara lowlands of the central, south and eastern plateau. Although Marillana A, Marillana B and Cleft Rock Shelter are also near to the scarp, the absence of LGM occupation at these sites may be due to the immediate environmental of these sites, such as the absence of freshwater springs similar to that near Milly's Cave.

After the LGM occupation episode Milly's Cave there is a roof fall and evidence for occupation reappears in the late Holocene around 200 BP. There is no change in the stone artefact technology between the LGM and late Holocene except for an increase in the size of artefacts made from raw materials other than chert such as bif, quartz and ironstone. In the late Holocene there is an increase in the proportion of artefacts made from exotic artefacts, suggesting a wider area of territorial exploitation than during the LGM. There were no backed artefacts, adzes or grinding pieces in the assemblage analysed from Milly's Cave.

8. Discussion and conclusion

INTRODUCTION

In this chapter I present a summary of the results from Marillana A, Marillana B, Cleft Rock Shelter and Milly's Cave. I show how the analysis of these four inland Pilbara rockshelters and previously reported archaeological evidence answers the two questions I asked in chapter one:

1. How did people in the inland Pilbara respond to the extreme environmental changes of the Last Glacial Maximum (LGM) at around 18,000 BP, and how and whydoes their response differ from people in surrounding areas?

2. What are the cultural, economic and demographic implications of appearance of new stone artefact types and increases in the intensity of site use and the numbers of sites occupied during the middle and late Holocene?

In this chapter I also comment on the usefulness of phosphorus analysis and magnetic susceptibility in inland Pilbara rockshelters and present the implications of my research for understanding the past of Aboriginal people in the inland Pilbara.

SUMMARY OF RESULTS FROM THE FOUR ROCKSHELTERS

Milly's Cave provides the earliest date of occupation of the four rockshelters, with artefact discard commencing before 19,000 BP. The low artefact density and the low proportion of artefacts with secondary working prior to 19,000 BP suggest that visits to Milly's Cave were brief and infrequent. During the LGM the rate of stone artefact discard increases at Milly's Cave without any significant changes in artefact technology or site use, suggesting that the frequency of occupation episodes increased during this period. Although there are no changes in technology or site use at Milly's Cave during the LGM, there is an increased use of locally available bif-origin chert indicating that the territorial range of the occupants was restricted during the LGM. Milly's Cave is the only site of the four examined here that has evidence of LGM occupation. Although the four sites are all near the escarpment the local environment of Milly's Cave includes a fresh water spring unlike the other three sites, which made have made it a more attractive location during the arid LGM conditions. A roof fall occurred at Milly's Cave sometime between 14,000 BP and 200 BP, and the site was not occupied again until after 200 BP.

Evidence of low levels of human occupation of Marillana A and Cleft Rock Shelter occurs before 13,000 BP, but there is no evidence that these sites were occupied during the LGM. At Cleft Rock Shelter there is a peak in artefact discard at 12,700 BP and no changes in artefact technology or site function, suggesting a peak in the frequency of visits to the site at 12,700 BP. A roof fall event at Marillana A occurred between 13,000 BP and 9000 BP. Analysis of phosphorus concentrations in sediments from Marillana A was useful in indicating that the intensity of human occupation significantly increased after 9000 BP. Analysis of magnetic susceptibility of sediments from Cleft Rock Shelter and Marillana A indicated that although magnetic susceptibility is sensitive to non-cultural as well as cultural processes, these two sites were probably briefly occupied throughout the history of their occupation. The results of the stone artefact analysis and sediment analysis suggest that there was no change in the duration of visits after 13,000 BP at Cleft Rock Shelter or 9000 BP at Marillana A.

After the increases in frequency of visits at 13,000 BP and 9000 BP, the next major change is the first appearance of a new stone artefact technology, represented by backed artefacts first appearing between 9000 BP and 3000 BP and adzes after 3000 BP at Marillana A and after 1700 BP at Cleft Rock Shelter. At Marillana A the first appearance of the new stone technology is coincident with an increase in stone artefact discard suggestive of increased frequency of visits, but rates of cultural material discard decrease sharply after 3000 BP. At Marillana A and Cleft Rock Shelter there are increases in the proportion of artefacts made from chert at the same time as the appearance of backed artefacts, but there are no significant changes in artefact manufacturing

technology or raw material availability. The increase in the numbers of chert artefacts may be linked to the appearance of backed artefacts because chert has highly predictable fracture mechanics and makes the production of formal tools more efficient. However, at Cleft Rock Shelter there is no indication of increased standardisation of artefacts at the same time as the new types appear, so efficiency in artefact manufacture was probably not a significant variable in the increased use of chert. The increased use of chert may have been an isochrestic decision, meaning that of the many functionally and economically equivalent options available in raw material procurement, artefact manufacturers chose to make a higher proportion of artefacts from chert at Marillana A at 9000-3000 BP and at Cleft Rock Shelter after 1700 BP. Sackett (1977:379) describes this sort of choice has as 'ethnically significant variation' that reflects 'culture historically significant units of ethnic tradition' (Sackett 1982:63).

Marillana B is first occupied sometime before 1800 BP, but is most frequently visited at around 1800 BP. No evidence of technological change, including new tool types, occurs at Marillana B. Cleft Rock Shelter shows a peak in cultural material discard at 1700-1100 BP. The four fragments with evidence of grinding found at Cleft Rock Shelter are dated to 1700-1100 BP, suggesting that grinding technology first appeared or intensified at the same time as the frequency of visits to Cleft Rock Shelter increased. Cultural material discard rates at Marillana A, Marillana B and Cleft Rock Shelter are low after about 1000 BP, but at Milly's Cave there is a peak in discard rates after 700 BP. There is no evidence of European contact with Aboriginal people, such as metal or flaked glass artefacts, at Milly's Cave, so this peak in occupation may have declined before about 200 BP.

How did people in the inland Pilbara respond to the extreme environmental changes of the Last Glacial Maximum and how and why does their response differ from people in surrounding areas?

Territorial reorganisation

Previous writers have suggested that the LGM was a period when humans in the Australian arid zone reorganised their patterns of land-use to exploit areas of reduced size near dependable resources (eg. Hiscock 1984, 1988, Veth 1993a, 1995). In regions surrounding the inland Pilbara, such as the northwest coast, Kimberley and interior, there is little direct evidence on LGM territorial reorganisation because sites are abandoned or show a reduction in occupation intensity. This evidence simply suggests that people *stopped using those particular sites* during the LGM and provides no convincing positive evidence for any changes in home range size.

Evidence for changes in territory size and mobility levels during the LGM at Milly's Cave suggests a reduction in the size of territory exploited for stone artefact raw material procurement. There are many sites throughout Greater Australia with traces of ephemeral LGM occupation, but the pattern at Milly's Cave is most similar to that observed at Colless Creek Cave and Louis Creek Cave in the Lawn Hill region, northwest Queensland and Fern Cave, southeast Cape York Peninsula. The similarities between Milly's Cave and these sites are discussed further below. At Colless Creek Cave and Louis Creek Cave artefacts made from stone more than 3 km from the shelters are absent in the assemblages discarded between 18,000 and 14,000 BP (Hiscock 1988:225-6, 241, 245-8). Hiscock (1988:245-8) suggests that people focussed more on the local gorge environment during the LGM because it was less risky than exploiting the plains. At Milly's Cave risk appears not to have been a significant variable in the reduction of territorial range because there is no difference in the efficiency of manufacture between local and exotic raw materials.

Fern Cave, on the southeast Cape York Peninsula, has permanent springs within two kilometres of the site, and like Milly's Cave and the Lawn Hill sites, a pattern of intensified use and increased use of local raw materials during the LGM (Lamb 1996). Intensive LGM occupation at Fern Cave is indicated by higher discard rates of artefacts and organic materials between 22,000 BP and 17,000 BP, compared to earlier and later periods of occupation (David and Chant 1995:401). Lamb (1996) and David and Chant (1995:402) interpret Fern Cave as evidence of a narrowing of resource catchments to a small but well-watered area in response to the aridity of the LGM.

Like the inhabitants of Fern Cave and the Lawn Hill sites, people at Milly's Cave focussed on advantageous features of the local geography to adapt the aridity of the LGM. Intensive LGM occupation at Milly's Cave suggests that people inhabiting the inland Pilbara during the LGM focussed more on the nearby steep northeastern scarp than the low relief Plateau. The northeastern

scarp drains the Plateau into the Fortescue, resulting in a high concentration of water that increases floral and faunal diversity and density compared to the Pilbara lowlands. The presence of a spring near to Milly's Cave may have been an additional advantage for LGM occupants and probably explains why Milly's Cave was occupied and Marillana A, Marillana B and Cleft Rock Shelter appear not to have been occupied during the LGM. To summarise, the evidence for territorial reorganisation in the arid zone during the LGM from Colless Creek Cave, Louis Creek Cave, Fern Cave and Milly's Cave suggests that people adapted similarly to the extreme glacial aridity throughout Australia by reducing their range to locations of dependable resources and an increasing their exploitation of local resources.

Mobility

The LGM abandonment or reduced intensity of occupation at sites in regions surrounding the inland Pilbara has led some writers to suggest that mobility greatly increased in response to glacial aridity (Smith 1989, Veth 1993a, 1995, no date, O'Connor *et al.* 1993, 1999, Thorley 1998). These authors use the evidence of reduced rates of artefact discard or abandonment of sites to argue for high residential mobility during the LGM. The problem with this argument or increased mobility is that it is based on an absence of evidence. Arguments based on the absence of evidence are unconvincing because they suffer from the problem that absence of evidence is not evidence of absence (Gingerich 1984). This is also known as the fallacy of the argument from ignorance, a type of argument that proposes that something (for example, increased mobility) must be true because it has not or cannot be proved false (for example, evidence of increased sedentism would be impossible at an abandoned site). The interpretation of increased mobility from absence of evidence further suffers from the problem of reductionism (Fodor 1981) where one archaeological manifestation, such as reduced intensity of stone reduction and site abandonment has only one behavioural characterisation, in this case increased mobility. A more parsimonious interpretation of site abandonment and reduction of cultural material discard rates during the LGM is that people visited these sites less frequently because they had relocated to, or narrowed their focus on, areas with more dependable resources. This territorial adjustment *need not require* increased sedentism or increased mobility.

The archaeological evidence from arid zone sites occupied during the LGM suggests that there were no changes in mobility compared to other periods. There are no indicators of increased mobility or sedentism, such as changes in the proportion or diversity of worked artefacts, at Colless Creek Cave and Louis Creek Cave during the LGM (Hiscock 1988:205-224, 235-238). Lamb's (1996) analysis of stone artefacts from Fern Cave found no evidence suggestive of changes in mobility or sedentism. The abandonment of sites in the north-west may be simply explained as a restructuring of resource exploitation, the kind that might be expected in dealing with seasonal changes. Evidence from Milly's Cave shows that during the LGM the frequency of visits increased while the duration of visits and the tasks carried out at the site did not change.

Demography and social organization

Some writers have suggested that the LGM in northwestern Australia was a punctuation event with a catastrophic contraction of population sizes and a reduction in the areal extent of exchange networks (O'Connor *et al.* 1993, Smith 1988:309, Veth 1993a, O'Connor 1990:446, 451 and Hiscock 1988:246). Available direct evidence, such as genetic or skeletal data, does not indicate, or has not provided any relevant evidence, that significant changes in population sizes occurred in Australia during the LGM (Adcock *et al.* 2001, Birdsell 1993, Freedman and Lofgren 1979, Pardoe 1990). Milly's Cave provides no direct evidence on the problem of demographic changes during the LGM and the evidence provided in chapter seven shows that it is not necessary to invoke demographic arguments to convincingly explain the changes observed at Milly's Cave.

Although arguments for demographic change during the LGM are unconvincing, there is some evidence for changes in social organization during this time. Ochre from the Hamersley Plateau occurs on the northwest coast at Mandu Mandu Rockshelter throughout the occupation sequence except from 20,000 BP to 10,000 BP (Morse 1993). The LGM interruption of exchange networks is also evident in the Kimberley with edge-ground axes, baler shell, mud clam and *Dentalium* sp. shell beads suggesting exchange over 300 km found in deposits dating to before the LGM occupation hiatus (O'Connor 1990:345-6, Balme 2000). This evidence suggests that there was a reduction in

the areal extents of exchange networks in the northwest quarter of Australia during the LGM.

The evidence of retraction of territorial area at Milly's Cave, the Lawn Hill sites and Fern Cave similarly suggests that social networks were less extensive during the LGM than other periods. Ethnographic observations of arid zone hunter-gatherers indicate that elaborate and extensive exchange networks are an important element of desert adaptations (Gould 1980, Yengoyan 1976). The change to an increased focus on local raw materials at Milly's Cave, the Lawn Hill sites and Fern Cave during the LGM suggests that raw material exchange activity declined at this time and that, contrary to expectations based on the ethnographic record, exchange networks may have *reduced* in these areas during the peak of glacial aridity.

Evidence of aggregation activity, such as complex art signifying corporate identities and high assemblage diversity, might be expected because Milly's Cave, the Hill sites and Fern Cave are in areas of dependable resources that multiple groups may have periodically visited (cf. Conkey 1980). The absence of changes to high assemblage diversity and the production of complex art during the LGM at intensively occupied sites such as Milly's Cave, the Lawn Hill sites and Fern Cave suggests that they did not become aggregation locales during the LGM. The absence of art at Milly's Cave may be explained by the platy and friable nature of the rockshelter walls that are unsuitable for engraving or painting. The rockshelter walls at Milly's Cave do not explain the absence of high assemblage diversity that is characteristic of aggregation locales, so it is possible to conclude that Milly's Cave was not an important aggregation site. To summarize, the available evidence suggests that population sizes and other population variables probably did not change significantly but that there was a contraction in the areal extents of exchange networks during the LGM.

WHAT ARE THE CULTURAL, ECONOMIC AND DEMOGRAPHIC IMPLICATIONS OF INCREASES IN THE INTENSITY OF SITE USE AND THE NUMBERS OF SITES OCCUPIED AND THE APPEARANCE OF NEW STONE ARTEFACT TYPES DURING THE MIDDLE AND LATE HOLOCENE?

The emergence of ethnographic cultural systems

The archaeological and ethnographic evidence discussed in chapter two indicates that cultural systems observed by ethnographers can be linked to archaeological evidence. In particular, the first appearances of backed artefacts, grinding stones and leiliras suggest changes in social, economic and gender relations. Previously reported archaeological research discussed in chapter two suggests that backed artefacts first appear at about 3700 BP, grinding stones at before 1600 BP and leiliras are currently undated.

The new archaeological evidence presented in chapters four to seven confirms previous evidence. Backed artefacts first appear at Marillana A at 9000-3000 BP and at 1700-1100 BP at Cleft Rock Shelter. The small numbers of backed artefacts found at Marillana A, Cleft Rock Shelter and the Newman Rockshelters suggests that they were not an important feature of the subsistence and technological activities carried out at these sites. Hiscock's (1994) risk reduction model suggests that backed artefacts were part of a technological change towards increased standardisation of artefacts in response to movement into new environments during the final stages of increases in sea levels. The first appearance of backed artefacts in the inland Pilbara at about 3700 BP negates the influence of rising sea levels, which stabilised at about 6000 BP (Chappell and Thom 1977). The record of human occupation of sites with backed artefacts up to 8000 years prior to the first appearance of backed artefacts suggests that the uncertainty of occupying new environments was not a relevant variable in the use of backed artefacts in the inland Pilbara. The lack of any change in standardisation of artefacts before and after the first appearance of backed artefacts at Cleft Rock Shelter suggests that increased efficiency of stone working was not a significant variable in the introduction of backed artefacts. The absence of any change in artefact manufacturing technological processes at Marillana A and Cleft Rock Shelter at the time that backed artefacts appear further suggests their economic importance was minimal. The evidence from Marillana A and Cleft Rock Shelter is poorly suited

to an economic explanation such as Hiscock's (1994) risk reduction model for the first appearance of backed artefacts.

Increases in discard rates of cultural material are coincident with the first appearance of backed artefacts at 9000-3000 BP at Marillana A and 1700-1100 BP at Cleft Rock Shelter and, according the archaeological and radiocarbon date evidence discussed in chapter two, with increases in occupation magnitude throughout the inland Pilbara at about 3600 BP and 1600 BP. The coincidence between the appearance of backed artefacts and increases in artefact discard suggests that the presence of backed artefacts may be a sample size effect and not represent any important cultural changes (Hiscock 2001, 1993, James and Davidson 1994). To test the possibility of the first appearance of backed artefacts at around 3700 BP as an effect of sample size I calculated the correlations between the number of backed artefacts and the artefact assemblage size (at the level of the excavation unit) for each site with backed artefacts. Table 8.1 shows the Pearson's product moment correlation coefficients for the relationship between numbers of backed artefacts and sample sizes of excavation units in inland Pilbara sites with backed artefacts.

Table 8.1 Summary of correlations between backed artefacts and stone artefact assemblage size at excavated inland Pilbara sites

r = Pearson's product moment correlation coefficient, bold type indicates $p(H_0) < 0.05$
*** = adze or geometric microlith**
^ = backed artefact

site	r	total number of new types	total number of artefacts	reference
Marillana A	0.324	2^	1227	this volume, chapter four
Cleft Rock Shelter	0.219	2^	569	this volume, chapter six
Mesa J J23	0.229	1*	293	Hughes and Quartermaine 1992:85
Newman Rockshelter	0.030	2^	266	Brown 1987:27-9
RR3-O	0.061	2*	168	Harris 2000:25
RR3-P	0.392	2^	156	Harris 2000:26
RR8-P	0.004	1*	152	Harris 2000:54
P4627	-0.262	1^	63	Brown 1987:44
P5313	-0.093	1*	30	Brown 1987:43

Table 8.1 shows that the strength of correlation between numbers of backed artefacts and excavation unit assemblage size is very low at the five inland Pilbara sites with backed artefacts. The low values of the correlation coefficients suggest that the first appearance of backed artefacts at inland Pilbara sites

represents a change in human behaviour and is not a result of sample size effects. Table 8.1 also shows that sample size effects do not explain the first appearances of other new Holocene stone artefact types such as adzes and geometric microliths. It should be noted that some of the large ranges of time allocated to major changes discussed in this project are a result of the small number of artefacts and the small number of radiocarbon dates obtained during excavations. To provide improved resolution on changes in stone artefact technology, future work in the inland Pilbara should involved excavations of *larger areas* of rockshelters than the typical one metre square. This would yield higher numbers of stone artefacts and provide more material for dating the sequence.

The increases in occupation magnitude at the time of the first appearance of backed artefacts suggest an increase in population density in association with a cultural change. By 'population density' I mean an increase in the intensity and frequency of human activity and probably, but not necessarily, an increase in the numbers of people. Dated rock art in the Pilbara suggests that the first appearance of backed artefacts may be related to a transformation of social systems in response to increased population density. In chapter two I demonstrated that there is a fluorescence of rock art in the Pilbara dated to a similar period to the first appearance of backed artefacts and increases in occupation intensity at the Newman shelters and Marillana A. This fluorescence of rock art in the inland Pilbara may indicate the first manifestation of corporate identities of groups (Davidson 1997a) and territorial structures similar to ethnographically observed socio-linguistic units (Taçon 1993).

Further research on Pilbara rock art may reveal a pattern similar to Cape York in northern Queensland where David (1991, David and Cole 1990, David and Chant 1995) has recorded a shift from an early homogenous engraving style to the appearance in the late Holocene of stylistically distinctive rock art provinces. David (1994, David and Cole 1990) argues that this represents a change from an extensive, open, exchange and social network to a more regionalised, closed system based on local exchange. Preliminary data on Pilbara rock art chronology supports a similar change from homogenous, non-figurative motifs to more stylised figurative motifs. Of the seven Pilbara motifs dated by Bednarik (2002a, 2002b) using microerosion analysis, two pecked outline circles are dated to c. 19,376 BP and c. 26,753 BP. Four pecked

anthropomorphic motifs and one 'scar' are all dated after c. 3670 BP. These data, although from a very small sample and from a technique yet to be repeated on any other Pilbara art, tentatively suggest that homogenous, non-figurative motifs preceded figurative anthropomorphic motifs in the inland Pilbara. Providing Bednarik's rock art chronology is accurate, it supports the argument that the appearance of backed artefacts and the fluorescence of rock art – particularly the figurative styles – represent cultural transformation related to boundary maintenance and exchange networks.

The form of backed artefacts, because it is not significantly determined by function and technology, may be something that identifies social units specific to time and place (Bowdler and Smith 1999), possibly representing a system of structuring relations between groups to manage conflicts and resource access in conditions of increased population density. Ethnographic evidence discussed in chapter two indicates that backed artefacts were associated with specific gender roles, suggesting that the appearance of backed artefacts represents an innovation or transformation of gender specific cultural systems such as subsistence behaviours or ritual activities.

A similar cultural transformation or innovation occurs with the first appearance or intensification of grinding technology in the inland Pilbara. Dates of 1700-1100 BP for grinding pieces from Cleft Rock Shelter and of before 1600 BP from P4507 provide the first evidence of dated grinding stones in the inland Pilbara. These dates for grinding in the inland Pilbara may be not be representative of the true date because of the strong correlation between grinding material and excavation unit assemblage size at P4507 ($r = 0.971$, number of grinding pieces = 92, total number of artefacts in excavated assemblage = 172). The correlation at Cleft Rock Shelter is lower with $r = 0.229$, but the number of grinding pieces is correspondingly lower ($n = 4$, total number of artefacts in excavated assemblage = 569). Cleft Rock Shelter and Marillana B are most intensively occupied just after 1800 BP, around the same time as the first appearance of grinding pieces. Evidence discussed in chapter two shows that a high number of sites were occupied for the first time at about 1600 BP and previously occupied sites were occupied more intensively. The similar timing of an increase in occupation magnitude to sites and the appearance or intensification of grinding activity suggests that grinding technology, like backed artefacts, may be related to cultural responses to increased population density.

Lee's (1968:35) observations of the hunter-gatherers of the Kalahari indicate that they can name 223 species of animals but they classify only 54 species as edible and hunt only 17 of these on a regular basis. Of the 85 plant species they recognise, 23 species provide them with 90% of their vegetable foods (Lee 1968:35). To Flannery (1973:307) this evidence suggests that hunter-gatherers divide food resources into 'first choice', 'second choice' and 'third choice' foods, turning to less preferred resources when they run out of the preferred species. Australian arid zone hunter-gatherers recognised a smaller variety of plant species as edible, probably due to the peculiar evolutionary history and isolation of Australia (Gould 1980:61). In the Australian Western Desert, Gould (1980:61) recorded 38 plant species identified by Aboriginal people as edible and eight plant species as staple foods (two of the eight are seed species).

Flannery (1973:307-8) writes that archaeological evidence of the earliest domesticates indicates that they were seed-crop cultivars derived from species that were 'third-choice' foods, requiring more work to procure and prepare. Flannery (1973:307-8) suggests that these 'third-choice' food resources were exploited by early farmers because there were seasonally abundant, increased the food yield per unit area and were storable. The switch from 'first-choice' foods to eating more 'third-choice' foods is something that Flannery (1973:308) proposes people did 'because they felt they *had* to, not because they *wanted* to' (emphasis in original).

Ethnographic evidence from the inland Pilbara may provide some insight into why people 'felt they had to' switch to an increased reliance on seed foods. Ethnographic evidence from the inland Pilbara discussed in chapter two indicates that seed-grinding was linked to storage and provisioning of food for ritual gatherings. Ethnographic evidence also suggests that edible seeds were ritual items in male initiation rituals and that seed-grinding, amongst other things, was an important activity performed by women for general subsistence and for supporting large ritual gatherings. Ethnographic information discussed in chapter two indicates that large ritual gatherings, such as male initiations, are important for maintaining group relationships and boundaries. This ethnographic information suggests that seed-based subsistence and grinding technology in the inland Pilbara was associated with cultural transformations involving gender-specific subsistence roles, large ritual gatherings and

maintenance of social networks. The archaeological evidence of an increase in population density at the same time as the appearance of grinding evidence suggests that consumption of seed foods is related to increased competition for food resources, probably caused by increased population density (cf. Smith 1986).

The link between population dynamics and cultural change

So far I have proposed that the appearance of backed artefacts and grinding technology represents transformations or innovations of cultural systems and are coincident with increases in occupation magnitude. The similar timing of cultural change and increases in occupation magnitude in the inland Pilbara suggest a causal link between occupation magnitude and cultural change. A possible link between cultural changes and changes in population dynamics is the effect of changes in population dynamics on the transmission of cultural information. If cultural information is perceived as an entity subject to the principles of Darwinian evolution, namely descent (or transmission) with modification, undirected variation in reproductive fitness and selection based on reproductive fitness, then the contexts of transmission becomes significant loci for cultural change (Shennan 2000).

Some authors, such as Cullen (2000) and Dawkins (1989), have proposed the metaphor of a virus for human cultural phenomena; a freelance entity that needs to 'borrow' other organisms' bodies to reproduce. Cullen (2000:203-4) suggests that culture can be considered as 'ecological assemblages of viral neuronal structures, distributed asymmetrically throughout the minds of a human community' with human minds acting as 'replicators by proxy' (Cullen 1993:199). Variations in cultural phenomena occur, at the most fundamental level, during the spontaneous re-association of ideas in human minds (Wittgenstein 1958), resulting from events such as failures of memory and errors in transmission (Cullen 2000:204, Shennan 1989:335, 2000:813). The undirected variation of ideas is constrained by the social, political and psychological milieux from which they emerge. These ideas can be selected for or against in the mind depending on their reproductive success within the human psyche or 'jungle of human sentiment' (Cullen 2000:183-9), which includes 'conscious human agency, emotions and intentions as a vast array of cognitive niches to which different populations of ideas adapt' (Cullen 1993:199).

Increases in the probability of cultural variation result from increased instances of transmission of cultural information and the concomitant increases in the probability of intentional and unintentional errors during transmission. Errors in transmission can occur on both sides of the relationship: the transmitter of cultural information can forget, err or deliberately modify the delivery, just as the receiver can misunderstand, deliberately misinterpret or ignore the information.

Processes of cultural transmission amongst inland Pilbara Aboriginal populations have been documented by Withnell and Clement. Withnell (1901:9) describes an example of vertical (from parent to child) and oblique (non-parent adult to a member of a younger generation) transmission:

> When elders meet, the children are gathered round to pay attention to ancient stories and traditions, and thus they are preserved through the ages.

Male initiation rituals are another example of vertical and oblique transmission noted by Withnell (1901:10):

> The elders then teach the novices fully and clearly all the ancient traditions, and what is expected of them on this occasion. The latter are then given about three days in camp to learn the chants and dances in connection with this important information.

After his brief visit to the Pilbara in 1896-99, Clement (1903:10) wrote that during the evenings of the circumcision ceremonial period

> huge fires are kindled, and the leaders sit around them with the candidates, teaching them the laws and traditions of the tribes, the boundaries of their territory, the reasons of their feuds with other tribes etc., etc., and the strict lines of their future conduct are strictly laid down for them.

Clement (1903:6-7) and Withnell (1901:5-6) both wrote that the custodianship of tarlow sites (sacred sites where ceremonies for the increase of resources are performed) is passed from parent to child for both sexes.

Evidence from Clement and Withnell suggests the circumcision ceremonies, the use of talow sites and the cultural systems that preceded them provide opportunities for transmission of cultural information. With probable increases in population density and size at around 3600 BP and again at 1600 BP, the likelihood of intentional and unintentional errors in transmission increases at these times. This results in increases in the probability of the acceptance of foreign ideas such as Western Desert section systems and the ethnographically observed westward spread of circumcision rituals. I propose that changes in population dynamics at about 3600 BP and again at 1600 BP in the inland Pilbara provided the right conditions in the contexts of transmission of cultural information for changes in cultural systems such as the emergence or increased importance of exchange systems, boundary maintenance, ritual gatherings and gender-based divisions in subsistence tasks. These systems would have been selected for because they confer selective advantages, such as increased efficiency in conflict resolution, in conditions of increased population dynamics.

CONCLUSIONS AND IMPLICATIONS

Human responses to the LGM

I have argued that a change towards reduced areas of territorial exploitation was an important response by human groups in the inland Pilbara to the aridity of the LGM. No catastrophic changes in demography or mobility are required to explain the archaeological record of the LGM in the inland Pilbara. The best explanation for LGM adaptations in the northwest quarter of Australia is that stable, low-density populations retracted to areas of dependant resources and maintained their Pleistocene land-use systems in reduced territorial areas. The success of this adaptation during the LGM was probably due to hunter-gatherer systems that already possessed a degree of cultural and technological latitude or pliancy that could accommodate the stresses imposed by glacial arid conditions.

The Pleistocene record of Tasmania provides further examples of hunter-gatherer's technological and cultural pliancy. The arid zone is generally considered to be the most forbidding part of Australia during the LGM, but Tasmania was also severely affected by the LGM when its much of its sclerophyll and rainforest communities were replaced by open grassland-steppe and glaciers formed in the central plateau (Bowler 1982). The archaeological record of LGM responses in Tasmania is complicated with some sites abandoned or occupied at very low intensities (i.e. Cave Bay Cave Bowdler 1984, Bone Cave, Allen 1989, and Warren, McNiven *et al.* 1993), some sites having unchanged intensities of occupation (i.e. Kutikina, Kiernan *et al.* 1983) and sites having more intensive occupation during the LGM (or just after) than at any other period (Nunamira, Cosgrove 1989, Parmerpar Meethaner, Cosgrove 1995b). In an attempt to describe a response to the LGM, McNiven (1994) has proposed that post-LGM settlement in south-west Tasmania was characterised by increased mobility and use of curated tool-kits. McNiven (1994) suggests that increased proportions artefacts made from exotic raw materials such as Darwin Glass (formed during a meteorite impact) and quartz indicate high mobility and increased proportions of thumbnail scrapers at Kutikina, Bone Cave, Nunamira, Macintosh 90/1 Shelter and Maneena Langatick Tattana Emita Cave represent curated tool-kits. On the other hand, Cosgrove (1995b) argues that the majority of raw materials at south-western sites such as Nunamira, ORS 7 and Parmerpar Meethaner are local and that the majority of thumbnail scrapers are made on local raw materials, reflecting limited inter-regional movement of stone resources and no major changes in mobility during and after the LGM. The significance of the diverse human responses and the negligible changes in demography and technology during the glacial period in Tasmania supports the evidence from Milly's Cave, the Lawn Hill sites and Fern Cave that humans were flexible in their adaptation to the harsh new conditions and were not highly stressed.

The most severely affected region inhabited during the LGM outside of Australia is central Europe due to its high latitude and proximity to the Fennoscandian ice sheet and Alpine ice masses (Williams 1998:2). Evidence of LGM occupation in central Europe shows that this adaptive flexibility is a universal hunter-gatherer trait rather than a specific Australian adaptation. During the LGM at Grubgraben, Austria there is an increase in non-endscraper technology such as armatures, burins, spalls, side-scrapers, perforators, notches and denticulates that Williams (1998:78) suggests reflect the increased importance of hide tailoring and outfitting activities. Also at this time is a small increase in the representation of marginal parts of horse (feet, lower legs and skulls) and reindeer (limbs, shoulders and rear quarters) (Williams 1998:58).

Following the LGM there is an increase in artefacts reflecting clothing and outfitting and an increase in the representation of marginal parts of subsistence animals (Williams 1998:78). From this evidence Williams (1998:80-1) concludes that local organisational modifications in hunter-gatherer systems at Grubgraben in response to severe climatic stress were relatively minor, including 'the kinds of adaptations one would reasonably expect in response to an increasingly dry and cold climate'.

West's (1997) examination of faunal remains deposited during the LGM at five central European sites, Grubgraben (Austria), Stanska Skala IV (Czech Republic), Sagvar (Hungary), Pilismarto (Hungary) and Pilisszanto (Hungary). During the LGM large bovids such as bison and cattle emigrated from central Europe resulting in a contraction of numbers of taxa and animals available to humans in an increasingly arid environment (West 1997:129). West (1997) shows that humans adjusted to these changes by modifying their procurement and processing strategies to accommodate a reduced number of ungulate species. The frequent representation of reindeer bones at the five sites during the LGM suggests that they were the prey of choice for humans in central Europe at this time. Reindeer carcasses were transported back to the sites where they underwent extensive processing including extraction of bone marrow and brains (West 1997:131). The meaty parts of horses are not frequently represented at the sites suggesting that they were consumed and abandoned at kill sites (West 1997:129). West (1997:131) concludes that human groups in central Europe during the LGM 'were probably not on the brink of starvation' and were equipped with organisational and technological skills to cope effectively within the harsh glacial environment.

The implications of these two European case studies are that human groups, even in *extremely severe* conditions, were much less affected by the LGM than has been previously suspected. The evidence from Milly's Cave in the inland Pilbara similarly suggests that there was no significant technological or economic reorganisation or indication of stress in response to the aridity of the LGM. The adaptation of hunter-gatherer cultural systems to severe glacial conditions may have been less spectacular than expected, instead resulting in changes similar to those involved in accommodating seasonal adjustments (Williams 1998:81). A further implication is that arguments for LGM refugia (Veth 1993a) may be superfluous. The evidence from Australian Pleistocene sites indicates that spatial and temporal configurations of local conditions and geography, such as the proximity of rockshelters like Milly's Cave, Fern Cave Colless and Louis Creek Caves to springs and gorges, may be more important for understanding patterns of human occupation than the identification of refuges as upland areas of biogeographical arks (Balme 1990, Balme and Hope 1995, Cosgrove 1995b:111-114, Davidson 1999:133). The four inland Pilbara sites discussed in detail here are similarly close to the Hamersley Plateau escarpment, but only Milly's Cave is occupied during the LGM. The crucial factor that made Milly's Cave a more attractive location during the LGM than the other three sites examined here was probably the local fresh water spring.

Holocene changes in technology, culture and demography

I have argued that Holocene changes in technology at after 3600 BP and around 1600 BP are associated with the first appearance or increase in importance of particular cultural systems. These cultural systems are based on analogy to ethnographically recorded cultural systems and include exchange systems, boundary maintenance, ritual gatherings and gender-based divisions in subsistence tasks. It must be emphasised that the link between technological types and cultural systems is an analogical association and I am not proposing a causal connection. It is possible that the new technological types appeared in quite different contexts to what I have suggested and were subsequently coopted or exaptated into the contexts observed ethnographically (cf. Gould and Vrba 1982).

Questions relevant to Holocene cultural changes include the possibility of the inland Pilbara as the origin of the Western Desert language (Veth 2000, McConvell 1996) or the bridge for the colonisation of the Western Desert by 'tula folk' (Jones 1968:190, Mulvaney 1969:115, 127). If the spread of backed artefacts and grinding technology indicates the spread of cultural systems analogous to those identified in ethnographically recorded Western Desert culture then these questions is 'probably not' because the timing of first appearance of the new technologies in the inland Pilbara and Western Desert is very similar. Backed artefacts occur in the inland Pilbara at around 3700 BP and in the desert interior at 3600 BP (backed artefacts and adzes at Kwerlpe, Smith 1988:247), the northwest coast at about 3000 BP (backed artefact at Yardie Well Rockshelter, Morse 1993:257). The 3700 BP date associated with the first backed

artefacts in the inland Pilbara has a standard error of 100 years and is therefore statistically equivalent to the 3600 BP date for the first backed artefacts in the interior. The similar timing of the first appearance of backed artefacts suggests that they were part of a synchronous multi-regional change and the direction of spread cannot be discerned.

The direction of the spread of grinding technology is more conclusive provided the early dates of about 10,000 BP for grinding technology at Puntutjarpa Rockshelter (Gould 1977) are accepted. If they are, then grinding technology appears to have moved from the desert interior to the inland Pilbara and northwest coast simultaneously. Grinding technology in the inland Pilbara dates to about 1700 BP and on the northwest coast about 1500 BP (Morse 1990:174-8). The problem with the suggestion of a spread from the interior to the coast is that the chronology of Puntutjarpa is uncertain. Eight radiocarbon dates were obtained for the site with two inversions and one seriously anomalous date; 3810±160 BP (I 3389) obtained from a depth below surface of 152-7 cm, compared to a date of 10,170±230 BP (I 5319) obtained from a depth of 117-122 cm below the surface (Gould 1977). This means that the date of the earliest grinding technology at Puntutjarpa is uncertain and is probably around 1000-500 BP (Smith 1986). This later date fits better with the increase in grinding technology at other sites in the desert and central Australian ranges at about 1400-600 BP (Veth 1993a:66-7, Smith 1988:334-8), as discussed in chapter two. Like backed artefacts, the first appearance or fluorescence of grinding technology in the interior occurs at about the same time as the earliest evidence of grinding in the Pilbara and the northwest coast. The archaeological evidence does not convincingly support a flow of people or artefacts between the coast and the interior. Instead, the evidence suggests during that the middle and late Holocene the northwest coast, inland Pilbara and interior were part of the same systems of technological change.

I have argued that at around 1600 BP not only is there the first appearance of grinding technology in the Pilbara, but there is also substantial evidence for an increase in population density and size. This is based on increases in cultural and non-cultural discard at occupied sites and on increases in the numbers of newly occupied sites. An increase in population dynamics at 1600 BP in the inland Pilbara may be related to similarly timed (1400-600 BP) increases in population suggested for the central Australian ranges (Smith 1988:325-326). I further argue that the increased population dynamics in the Pilbara at 1600 BP may have caused the cultural changes analogous to ethnographic systems. Increases in population dynamics have a multifarious effect on the processes of descent with modification that characterise cultural evolution (Shennan 2000:821). The cause of the population increase is undetermined; a key factor may be climatic conditions, but there is currently no direct evidence from the Pilbara on Holocene climate changes or no reason to suspect significant climate changes in the inland Pilbara after 7000 BP (Wyrwoll pers. comm. 2002). At about 3600 BP in the inland Pilbara and about 1600 BP in the inland Pilbara and the interior there were increases in population size that altered contexts of transmission of cultural information and increased the probability of cultural changes, which manifested archaeologically as backed artefacts in the inland Pilbara at about 3600 BP and grinding technology in the inland Pilbara and the interior at about 1600 BP.

In conclusion, the inland Pilbara evidence presented in this study suggests that human groups during the LGM were more flexible in their response to glacial conditions than previously assumed. This supports finding of research in parts of the world more severely affected by glacial conditions than the inland Pilbara. Technological changes in the inland Pilbara occur in the form of backed artefacts after 3600 BP and grinding technology after 1600 BP. Ethnographic analogy suggests that these technological changes represent transformations or innovations in exchange systems, boundary maintenance, ritual gatherings and gender-based divisions in subsistence tasks. Increases in occupation magnitude at about 3600 BP and 1600 BP in the inland Pilbara are causally linked to the cultural changes because of the increased the probability of cultural change during conditions of increased population dynamics.

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