Between the Desert and the Gulf:

Evolutionary Anthropology and Aboriginal Prehistory in the Riversleigh / Lawn Hill Region, Northern Australia.

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Untitled landscape, Lawn Hill, Lenny Cubby, 2003.

"Having mastered the capacity to cross water, the true barrier to the colonisation of the Australian continent lay not in the occupation of the tropical north but in the ability to establish and maintain human settlement in the arid country to the south" (Jones 1987:666)

PREFACE

This work was completed in the School of Philosophical and Historical Inquiry during the period of March 2002 to March 2007.

The work was funded by an Australian Research Council Linkage Grant 2002-2004 (LP0211430) to Dr. Judith Field (University of Sydney), Professor Michael Archer (Australian Museum) and Mr. Andrew Border (Environmental Protection Agency, Queensland). Comprehensive consultations, and permissions obtained to do the research, were undertaken with the Waanyi Aboriginal Community and the Waanyi Nation, the Carpentaria Local Aboriginal Land Council and the Waanyi Ministerial Advisory Committee.

Part of this work has been published elsewhere:

(i) Slack, M.J., Fullagar, R., Border, A., and J. Field. 2005 "Late Holocene occupation at Bunnengalla 1, northwest Queensland", *Australian Archaeology*, 60, 54-57.

(ii) Slack, M.J., Fullagar, R.L.K., Field, J.H., and A. Border 2004. "New Pleistocene dates for backed artefact technology in Australia", *Archaeology in Oceania*, 39, 131-137.

Parts of this work have been presented in reports and at national and international conferences:

Slack, M.J. 2007. *Historical Associations of the Waanyi with Lawn Hill National Park*, Experts Report for Waanyi Native Title Claim for the Carpentaria Local Aboriginal Land Council.

Fullagar, R., Slack, M.J. 2004. *Cultural assessment and cultural heritage management plan in relation to the establishment of infrastructure at Lawn Hill (Creek) Resource Reserve, northwestern Queensland.* Unpublished report to QPWS.

Slack, M.J. 2006 *There ain't no easy road: the role of inland tropical inland Australia in models of arid zone settlement.* Australian Archaeological Association Conference, Beechworth, Victoria.

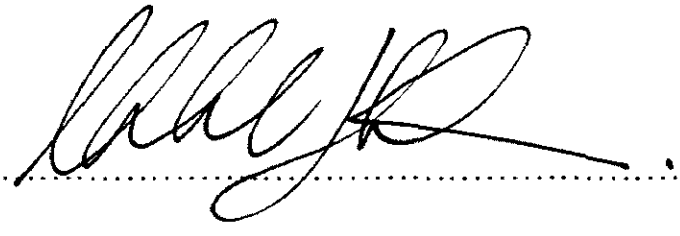
Slack, M.J. 2005. *Early Human Occupation in northwest Queensland.* Invited Seminar, Department of Archaeology, La Trobe University, and Department of Archaeology and Sociology University of Queensland.

Slack, M.J. 2004. *Subsistence strategies in Late Pleistocene northern Australia.* Society for American Archaeology Annual conference, Montreal, Canada.

Slack, M.J., Fullagar, R., Field, J., and A. Border. 2003. *Late Pleistocene settlement in northwest Queensland,* Australian Archaeological Association Conference, Jindabyne, NSW.

DECLARATION

I declare that the work in this thesis is the result of my own research and all references to the work of other researchers have been acknowledged. This thesis has not been submitted in whole or in part for any other degree.



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Laboratory analysis was assisted by Amy Stevens, numerous undergraduate students, and even Jeanette Slack. Specialist advice was provided by Winston Ponder (shells), Bethan Charles and Melanie Fillios (fauna), Veerle Rotts and Richard Fullagar (use wear), Braddon Lance (statistics), Darden Hood and the late John Head (radiocarbon).

The development of ideas presented here has been informed by discussions with the following people: Jim Allen, Bob Bettinger, Andrew Border, Richard Cosgrove, Lesley Head, Peter Hiscock, Pat Faulkner, Brian MacEanany, Dave Meltzer, Jim O'Connell, Colin Pardoe, Annie Ross, Sean Ulm, and Peter Veth - none of whom are at all responsible for any errors, omissions or bias.

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Finally, and most importantly I thank the Waanyi community. I have been lucky to have worked with the Waanyi for the last nine years. I specifically thank those elders who spent extended periods of time in the field excavating and sorting with me: Peter Bell (dec.), Barry Dick, Richard Brookdale, Jackson Diamond, Reggie Carlton (dec.), Des Carlton (dec.), Lenny Cubby, Gordon Douglas, Bobby George, Nancy George, Don George (dec.), Erick King, Joseph Moreland, Eunice O'Keefe, Sally O'Keefe (dec.), Yvonne O'Keefe and Peter O'Keefe. This project also developed Indigenous traineeships and the following Waanyi assisted greatly in fieldwork as a part of training: Casey Aplin, Brandon Brookdale, Melissa Cairns, Chantelle Holt, Bradley King, Berrylene King, John Gallagher, Gadrian George, Ngaire George, Larissa George, Rex Gregory, Warren O'Keefe, and Gilbert Pitt.

ABSTRACT

This thesis applies an evolutionary approach to the regional prehistory of the Riversleigh/Lawn Hill region of Northern Australia. The research examines *(i)* the timing of colonisation of Australia and *(ii)* the nature of subsequent arid zone settlement and adaptation. Both of these research concerns are addressed through development of a regional settlement and subsistence model that is based within an overall framework of evolutionary theory and specifically from various models used by Human Behavioral Ecology (HBE). Using this approach this research presents new regional archaeological data and develops *(i)* a new model of north Australian Pleistocene settlement relating to Lake/Gulf of Carpentaria and *(ii)* an evaluation of competing models of Aboriginal subsistence during different climatic phases, with a specific focus on the Last Glacial Maximum (LGM).

The model of settlement and subsistence for the study region sets out expected responses of hunter-gatherers to large scale climatic changes over the last 40,000 years. These expectations are evaluated by quantifying changes in the nature of flaked stone technology, and in the frequency and range of faunal remains in archaeological sites.

I argue that climate change forced modifications to hunter-gatherer behaviours that are evident in the archaeological record. Significant behavioural changes occurred during the LGM, and included refuge occupation along the Gregory River, specialization in resources of low rank and conservatism in lithic reduction strategies. During improved climatic conditions, residential mobility increased, and subsistence expanded in range to include more high ranked resources, and lithic reduction altered to include new forms. Similar

more subtle changes to settlement and subsistence are also evident during the early and mid Holocene periods.

The results of this thesis support a 'short' 40,000 - 45,000 year chronology of Aboriginal colonisation of Australia and a bio-geographic model of LGM settlement that included refuge occupation of the Gregory River corridor, but probably not Lawn Hill (*after* Veth 1989, 1993). The bio-geographic model used in this thesis stresses the importance of the HBE approach, and an emphasis on developing detailed local and regional archaeological chronologies.

The results of this research show that although further refined data concerning the palaeo-environmental record is needed, the functional approach of Human Behavioural Ecology is a valuable methodology for examinations of the archaeological record, providing theoretical rigor to local scale studies that can contribute to regional and more general models of human behaviour.

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1.1 Introduction and background

This thesis examines the human settlement of the Riversleigh/Lawn Hill region, northwest Queensland, Australia. It presents the results of excavation and analysis of eleven archaeological sites, including two rockshelters excavated and previously reported from Lawn Hill (Hiscock, 1988). There are two aims to this thesis. The first aim is to provide new data that aids in addressing two important questions in Australian prehistory: (i) when did people arrive in Australia and (ii) what was the timing and nature of the colonisation of the inland areas of the continent. The second aim is to determine whether evolutionary theory, as applied to archaeological data, can provide a useful interpretive framework for investigations involving long time depth.

1.2 Research Questions

1.2.1 Colonisation of Australia

Most researchers agree that initial human arrivals in Sahul (greater Pleistocene Australia) occurred in the north of the continent (see Allen *et al.* 1977). However, opinion is divided as to how, and by what routes, people colonised the continent: a northern route through New Guinea, or from the north west through the islands of Indonesia and Timor (Birdsell 1975, 1977; Bowdler 1977; Irwin 1992; Allen and O'Connell 1995; O'Connell and Allen 1998, 2004). Different colonisation routes may signify different material cultures and adaptation strategies for colonising populations. For example, colonisation from Timor is often argued to have been made by people with a coastal economy (see Chappell 1993, 2000, Pardoe 2006). The alternative route through New Guinea and then south into

Australia, via the Carpentaria Plain, did not necessarily require the same maritime adaptive strategies.

Recent research has paid most attention to the southern migration route which is supported by the growing number of reported Late Pleistocene archaeological sites in northwestern and northern Australia, including Carpenters Gap, Riwi, Nauwalabila I and Malakunanja II (see Balme 2000; Bird *et al.* 2002; Fifield *et al.* 2001; Roberts *et al.* 1990a, b, c, 1994). At some of these places the antiquity of occupation is disputed (see O'Connell and Allen 1998), whilst at others an extensive hiatus in the archaeological record occurs soon after the first evidence of human occupation. At most of these sites there is little detailed discussion of the archaeological record for the initial settlement period.

Alternatively, colonisation of Australia may have followed a more northern route. The northern route into Australia may have transversed the east coast of Sahul, or inland around the shores of the Gulf of Carpentaria. Currently there is only one archaeological site on this northern route: Ngarrabullgan Cave in north eastern Queensland (David *et al.* 1997). No early sites are known surrounding the shores of the Gulf of Carpentaria. However, Colless Creek Cave, 200 km inland to the south of the Gulf, has provided compelling evidence for early human settlement in this region (Hiscock 1984a, 1988).

The research model formulated for this study explores a colonisation route from New Guinea via the Gulf of Carpentaria. The shores and surrounding landscape of the Gulf, whilst well vegetated with savannah grasses and resource rich, were vast and mostly devoid of exposed parent rock. They have since been flooded, and whilst material culture associated with early occupation might be present in these flooded areas, the chances of its discovery are remote.

A number of sizeable freshwater rivers feed into the southern reaches of the Gulf of Carpentaria including the Nicholson, Gregory and Leichhardt Rivers. These rivers may have provided corridors for human settlement within rich riverine environments (after Veth 1989, 1993).

The study area is well placed to provide insights into the timing of colonisation, the routes taken and the technology transported into Australia. The geology and topography of the region is known to support the preservation of suitable occupation sites and previous studies have highlighted the potential of the region to yield lengthy cultural sequences (*i.e.* Hiscock 1984a, 1988).

1.2.2 Settlement of the Arid Zone

Whilst there is strong archaeological evidence that humans penetrated what is now the most extreme arid regions of the continent by about 40,000 years ago (Bowler *et al.* 2003; Grun *et al.* 2000; Roberts *et al.* 1996; Smith and Sharp 1993; Smith *et al.* 1997, 2001), the timing and nature of subsequent settlement is still hotly debated (see Hiscock and Wallis 2005). The antiquity of arid zone occupation is less of an issue, than the mode of settlement, particularly during the Last Glacial Maximum (LGM). There are a number of competing models of human settlement and subsistence for the arid zone, but none have been conclusively resolved (*e.g.* Hiscock 1988; Hiscock and Wallis 2005; O'Connor *et al.* 1993; Smith 1988, 1989a, 1989b; Thorley 1998a, b, 2001; Veth 1989, 1993).

Three competing models for arid zone occupation have been proposed to account for settlement since colonisation: *(i)* continual occupation; *(ii)* fluctuating occupation; and *(iii)* a bio-geographic model. The primary difference between these models relates to the nature of occupation of the arid zone during the LGM. Was the arid zone occupied continuously, was it abandoned, or was there a pattern of occupation intermediate between the two that occurred, with expansion and contraction from refuge areas? Three locations have been

proposed as refuge areas: the Hamersley Plateau, the Kimberley Region, and the south-western Gulf of Carpentaria. Archaeological evidence from these localities is limited and the sites have often been interpreted differently by researchers (*i.e.* P. Brown 1987; Comtesse 2003; Marwick 2002a, 2002b).

The south-western Gulf of Carpentaria region has been proposed as a region where 'refuge' occupation occurred during the LGM (see Hiscock 1988; Hiscock and Wallis 2005; O'Connor and Veth 2005; Smith 1988; Veth 1993). To further test this proposal, this research focuses on the permanent flowing rivers of the south-western Gulf of Carpentaria, where 'refuge' occupation is most likely to be found.

1.3 Research Approach

This research presented here is a regional study of the archaeology of the south-western Gulf of Carpentaria, where a detailed settlement and subsistence model based on evolutionary theory is developed to explore timing and patterns of occupation.

Recent archaeological studies in Australia have applied the evolutionary theoretical approach (Barton 2001; Clarkson 2004; Cosgrove 1995, 1999; Cosgrove and Allen 2001; Cosgrove and Pike-Tay 2002, 2004), but only Cosgrove's is anchored in a secure chronology of considerable time - depth. The strength of the approach is that it uses functional rather than historical explanations of past human behaviour. Functional arguments explain processes that operate universally rather than being contingent on specific events (O'Connell and Bird 2006). The evolutionary theoretical background provides a strong basis by which to distinguish behaviour in the archaeological record while permitting consideration of past behaviours that may be invisible. Evolutionary models readily lend themselves to the study of flaked stone artefacts; their production, use and archaeological signatures (Murray 2002). This is important, as the archaeology of northern Australia is necessarily built upon the stone artefact record.

The Australian Pleistocene archaeological record includes relatively few sites, with few opportunities for the development of substantial theoretical models, and yet generalisations have often been made across the entire continent. Examples include the broad application of a "core tool and scraper tradition" (see Bowler *et al.* 1970; Bowdler 1981; Bowdler and O'Connor 1991; Dortch 1977; McCarthy 1964, 1967; Smith and Cundy 1985; but also see Clarkson and David 1995; Hiscock and Attenbrow 2002), simple colonisation models (e.g. Bowdler 1977), and simplistic notions of human causality in megafaunal extinctions (Jones 1968, 1969, Flannery 1994; Roberts *et al.* 2001). Evolutionary approaches specifically applied to regional studies aim to explain changes in settlement and subsistence on the basis of predictions based on a knowledge of human behaviour. These studies aim to avoid weak generalizations and provide readily testable models.

In regard to the regional archaeological model and evolutionary models this research further aims to investigate the changes and continuity in settlement and subsistence in the study area with particular reference to mobility, activity locations, and technological innovation. Sites investigated in this study cover different time periods and different environmental contexts ranging from the Late Pleistocene up to the historic period. Variability in stone artefact reduction across time and space will be investigated to chart changes in mobility and subsistence strategies. Analysis of faunal material, where available, will also aid in identifying target prey. These results will then be compared with predicted responses in human behaviour, developed from evolutionary anthropological models and human behavioural ecology.

1.4 The Study Region

Riversleigh/Lawn Hill is located in far north-western Queensland adjacent to the Northern Territory border, approximately 250 km south of the modern Gulf of Carpentaria coastline, and 400 km northwest of the city of Mount Isa (Figure 1.1). At the height of the

Last Glacial Maximum between 30,000 and 18,000 BP the study area was at the very heart of the Sahul continent and well within the arid zone. However, consistently flowing spring - fed streams have always supplied water, independently of droughts and climate change.

Today the entire region is found within the traditional country and Native Title claim area of the Waanyi people (Trigger and Fietz 2003). It is situated at the transition from savannah woodlands and blacksoil plains (associated with the Gulf of Carpentaria), to the rugged plateau of the Barkly Tableland. Most of the research presented here has been conducted at the junction of these land units within Boodjamulla (Lawn Hill) National Park and the Riversleigh World Heritage Area. Seven perennial water courses flow through Boodjamulla National Park in a north easterly direction - Elizabeth, Musselbrook, Louie, Colless and Lawn Hill Creeks, and the Gregory and O'Shannassy Rivers. Along the eastern edge of the National Park the combination of these water courses and exposed Proterozoic, Middle Cambrian, and Late Tertiary rock formations has resulted in deeply entrenched gorge systems. At Riversleigh the limestone formations also contain a vast fossil record extending from c. 5 million years ago to the recent past (Archer *et al.* 1991). It is along the entrenched gorge systems that the archaeological signature is strongest. Caves, rockshelters and extensive open sites including middens and lithic scatters are common (Slack 2002a; Van der Meer 1997).

1.5 Contemporary Aboriginal Associations

The Waanyi people are speakers of the Pan Nyungan language group and share a common affinity with the Garawa People across the Northern Territory/Queensland border. Tindale (1974) shows Waanyi Territory as extending from far western Queensland into the Northern Territory, encompassing both the plateau and the plain of the Gulf. This is probably accurate for the late twentieth century, but by this time most of the dislocation

and upheaval of the Aboriginal population of the region had been completed, resulting in the Waanyi expanding their territory to encompass neighbouring language groups.

The areas where this research has been undertaken occur along the boundaries of Waanyi-Ngborindji and Waanyi-Indjilandji-Wakabuna. The Waanyi, Ngborindji and Indjilandji people appear to have been from the same cultural block (Sharp 1939). These associations are fairly recent and most likely the result of historical connections as a result of the fusing of other related groups (see Trigger 1980, 1982a, 1982b, 1985, 1987a, 1987b, 1992; Trigger and Fietz 2003). Substantial disruption is known to have taken place to Aboriginal territories with the onset of European settlement. Other neighbouring Aboriginal language groups including the Ngborindji were decimated by the combined effects of frontier violence and European introduced diseases. The Waanyi who are described as 'hill people' by Trigger (1992) are thought to have retreated within the gorge systems of the various rivers that spread across the region very soon after contact (Slack 1998, 2002a, b; Trigger 1992). During the historical period, the Waanyi expanded their territory to encompass the Ngborindji, with an eastern boundary following the west bank of the Gregory River.

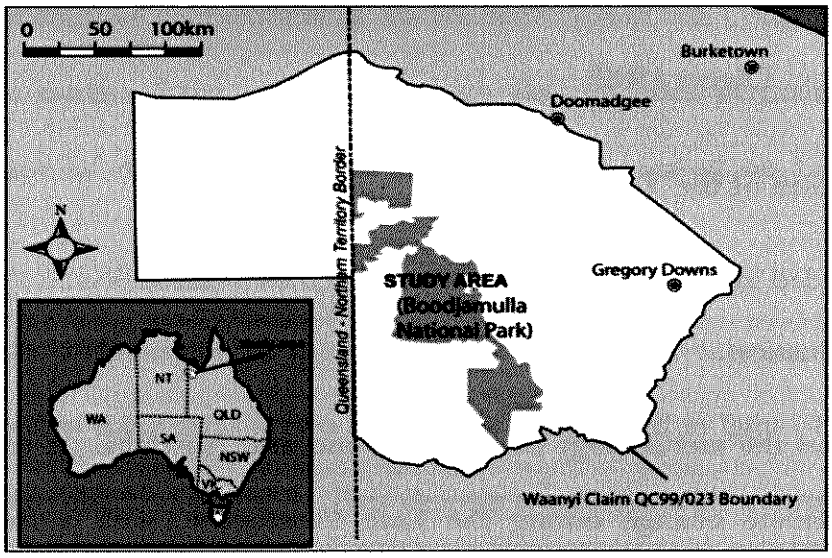

Figure 1.1: The southern Gulf of Carpentaria in northern Australia showing the research area of Boodjamulla (Lawn Hill) National Park and Riversleigh World Heritage Area within the Waanyi Native Title Claim Area and the regional centres of Doomadgee and Burketown.

1.6 Previous Research in the Study Area

Previous archaeological research in the study area is comprised of both academic research and commercial consulting surveys (Border and Hayes 1997; Dymock 1982, 1993; Fullagar and Slack 2004; Hiscock 1988; Hiscock and Hughes 1980, 1984; Pickering 1997; Robins and Trigger 1983; Slack 1998; Slack *et al.* 2004, 2005). Initial interest in the region commenced with excavations by Phil Hughes and Ken Aplin, who obtained a Pleistocene date from Colless Creek Cave at Lawn Hill in the centre of the study area (Hughes 1983). Peter Hiscock subsequently completed a PhD thesis on this and other local sites in 1988 (Hiscock 1988). Graeme Walsh conducted a rock-art census of the Lawn Hill gorge area in 1982, and Andrew Border conducted a similar study of Lawn Hill in 1988 and Musselbrook Creek in 1989 (Border 1988, 1989; Walsh 1982, 1985). In 2002 a historical archaeology MA focused on the entire study region (Slack 2002).

Research at Riversleigh has included an historical honours thesis (Slack 1998), an honours thesis based on surveys by van der Meer (1998), and a women's history project (Smith and Van der Meer 2000). During the 1990s, various consulting projects focused on the eastern plains area of the region in the course of the development of the Century Zinc project (*e.g.* McKay 1992a, b, c; Trigger 1992).

1.7 Organisation of the Thesis

The thesis is divided into 8 chapters.

Chapter 1 Introduction.

Chapter 2 reviews the archaeology of northern and arid Australia. It commences with a discussion of climate change during the Late Pleistocene, with a focus on northern Australia and the research region. Competing models of colonisation and reviews of the archaeological data are presented. The chapter then discusses the competing models for arid zone settlement, and assesses the archaeological evidence that supports these models.

Chapter 3 provides a detailed review of the results of previously excavated sites at Lawn Hill by Hiscock (1988). Hiscock's model of the relationship between lithic technology and settlement is explored, and his overall model of fluctuating arid zone occupation is reviewed.

Chapter 4 is a detailed discussion of the theoretical approach used in this research. The key concepts of evolutionary theory are presented, and a comprehensive discussion of the models of human behavioural ecology is presented. These models are reviewed and illustrated by archaeological examples.

Chapter 5 builds upon the theory presented in the previous chapter. It presents a land - use model based on the concepts of human behavioural ecology that will be applied to the research region. In developing this model the chapter also provides environmental background for the study region.

Chapter 6 and 7 are the primary result chapters of the thesis, with presentation of studies of excavated and surveyed sites. Chapter 6 focuses research on sites near and more distant from the most substantive watercourse of the research region, the Gregory River. Chapter 7 focuses on the north of the study area which also includes permanent streams, and explores the nature of the archaeological record at sites located on far less permanent watercourses.

Chapter 8 provides a discussion of the results and the main conclusions of this research. The data presented in the previous two chapters is interpreted in light of the evolutionary models presented in chapters 4 and 5. This chapter concludes with a summary of the main findings of the research, and reviews how the Boodjamulla data is important in reconstructing Australia's Pleistocene prehistory.

Chapter 2

The Archaeology of Northern Australia and the Arid Zone: Chronologies and Settlement Models.

2.1 Introduction

The questions of when and how people arrived in Australia and their subsequent colonisation of the arid zone are important issues for northern Australian studies. Prior to discussing the research region in detail it is necessary to place the study within the wider Australian context. This chapter discusses the models of the colonisation of northern Australia and the arid zone. It provides assessments of current published site data, and frames discussion within the context of contemporary understandings of palaeo-climatic regimes.

2.2 The Australian Climate: the last 50,000 years

The Australian climate has always played a large role in human subsistence systems, from first arrivals to the present day. No matter when the hunter-gatherers arrived in Australia they confronted a continent of extremes. Environments varied between sand dune deserts, tropical rainforests and alpine zones. Over the last 50,000 years, global climate change has had dramatic effects on Australia. The onset of the Last Glacial Maximum, its duration, and the subsequent possible impacts of the Younger Dryas (see Turney *et al.* 2006), combined with sea level rises and the flooding of the Gulf of Carpentaria by 10,000 years ago, have all influenced northern Australia. These pronounced changes in climate and environment attest to the challenges for human populations since first arrival.

Over the last 50,000 years there have been numerous and extreme oscillations in the climate of northern Australia. This research is primarily interested in the following six

phases: *(i)* the colonisation period (MIS3 50,000-30,000 BP), *(ii)* the Last Glacial Maximum (MIS2 30,000-18,000 BP), *(iii)* the post LGM Late Pleistocene (18,000-10,000 BP), *(iv)* the Early Holocene (10,500-5,500 BP), *(v)* the Mid Holocene (5,500-2,000 BP), and *(vi)* the recent past (2,000 BP - present). Each of these phases is marked by significant changes in climate. These six phases are necessarily broad, as there is no detailed environmental history known from the study area, and therefore reconstructions are necessarily based on extrapolation of palaeo-environmental data from sources up to 500 km distant.

2.2.1 Phase 1 (50,000 - 30,000 BP)

During the period between 50,000 and 30,000 BP, humans entered Australia, as dramatic changes to the climate and environment of Northern Australia were in train. Sea levels around Australia fluctuated significantly due to cyclic growth and decay of the northern continental ice sheet resulting in the continual reshaping of the continent. From about 62,000 BP, sea levels rose after a low-stand at 85-90 m below present, with four high stands: at 32,000, 36,000, 44,000 and 49,000 - 52,000 BP (Lambeck *et al.* 2002:201). During the height of the LGM sea levels fell to c. 130 m below present, and by 26,000 BP they had reached 70 – 50 m below present (Chappell 1983, 1991, 1993, 2000, 2002; Harrison 1993; Lambeck and Chappell 2001; Magee and Miller 1998; Nanson *et al.* 1991; Roberts *et al.* 1991). Lambeck *et al.* (2002) note that the ice volumes that mark the end of this phase were reached at approximately 19,000 BP. Up to this point the drops in sea level appear to have been rapid and, at times of colder periods, sea - level oscillations might have reached magnitudes of tens of metres in under 1,000 years (see Chappell 2001; Chappell *et al.* 1996; Lambeck *et al.* 2002; Yokoyama *et al.* 2000, 2001).

During this phase Australia and New Guinea constituted one landmass, referred to as Sahul. The Gulf of Carpentaria was almost an enclosed body for most of the period and constituted a brackish estuarine water mass, but between 80,000 and 40,000 BP sea levels

are thought to have repeatedly breached and withdrawn from Gulf/Lake Carpentaria (Chivas *et al.* 2001:19). It is thought that colder and wetter conditions than today prevailed in Sahul with several mega-lakes featuring in central Australia (Lambeck and Chappell 2001; Lambeck *et al.* 2002; Nix and Kalma 1972).

Between 40,000 BP and 35,000 BP the Fly River in New Guinea, which itself had previously consisted of a large fresh-to-brackish water body within the Arafura basin, was diverted to the Carpentaria Basin by the Oriomo Uplift. From about 35,000 BP to 26,000 BP, the climate became wetter with enhanced wet-season precipitation for the Gulf of Carpentaria. (Jones and Torgersen 1988; Torgersen *et al.* 1988:258) (Figure 2.1).

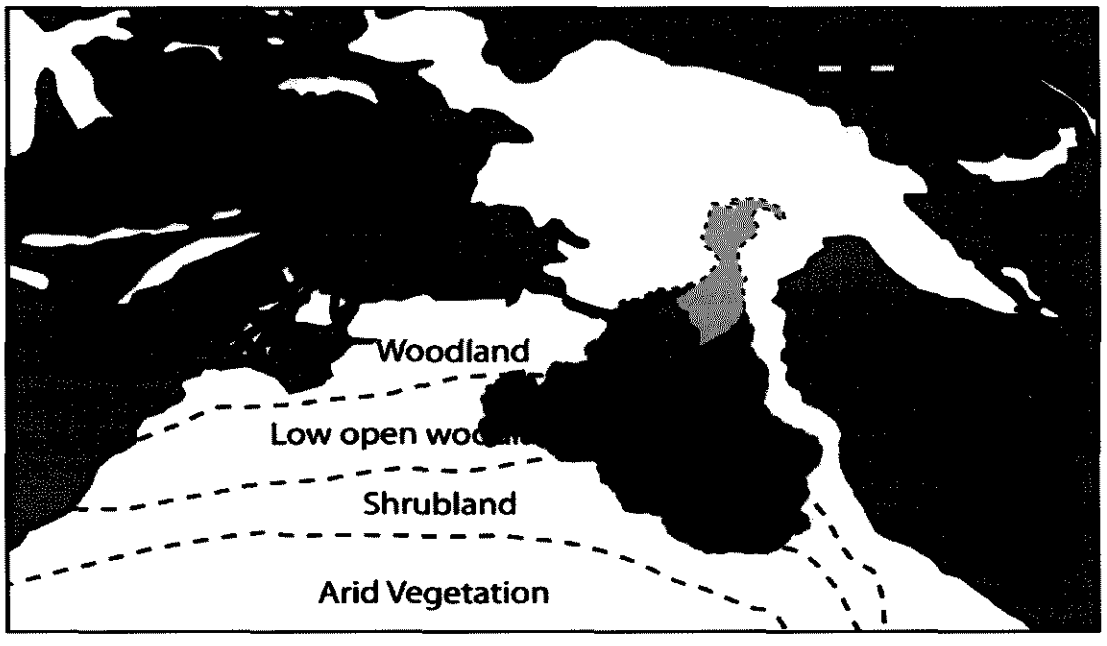

Figure 2.1: Northern Australia during the period 50,000-30,000 BP showing the extent of different vegetation communities during a highstand period. The drainage basin of the Gulf of Carpentaria is shown in dark green and the drainage basin of the Fly-Strickland in light green.

2.2.2 Phase 2 - the LGM (30,000 - 18,000 BP)

From 30,000 BP until approximately 18,000 BP the Australian climate deteriorated significantly. This period known as Oxygen Isotope Stage 2 (OIS2) and is marked by a steady gradual drying and cooling of the continent, massive drops in sea level, reduced

precipitation, and greater prevailing winds. Until recently it was believed that the LGM had a relatively sudden onset, lasting only a couple of thousand years. However, recent research has shown the LGM to be more drawn out, enduring for c. 10,000 years. LGM ice volumes were approached at about 30,000 BP, increasing only slowly during the next 10,000 years. The onset of the LGM is represented by the minimum sea levels recorded; beginning around 30,000 BP (Lambeck and Chappell 2001; Van der Kaars *et al.* 2006). Fine resolution analysis of the Greenland polar ice core record and ocean sediment core records from the northern hemisphere indicate that the interstadials during the last glaciation were subject to considerable fluctuation at certain times and that "transitions between longer warm and cold periods... occur over periods of less than 10 years" (Taylor *et al.* 1993:435) and that similar trends might also relate to the southern hemisphere albeit with a time lag (Bluiner and Brook 2007). This issue is also raised by Chappell (2001) but who also notes that these oscillations have only "so far been recognized in records from northern hemisphere sites, both sedimentary and archaeological" (Chappell 2001).

Regardless of the potential for abrupt short term changes during this period, Sahul experienced significant reductions in temperature, severe droughts, high winds, dust storms. Declines in atmospheric CO_2 levels persisted and in some areas of Northern Australia, dune fields expanded (Hesse *et al.* 2004; Hesse *et al.* 2005). The effects of the LGM were dramatic with a substantial expansion of the arid zone and associated vegetation and hydrological systems which have not yet been repeated (DeDeckker 2001; DeDeckker *et al.* 2003; Horton 1993; Lambeck and Chappell 2001).

The large scale effects of the LGM included an increase in the size of the Sahul landmass by up to 30% at this time with documented local sea drops of 130 m below present by 19,000 ago (Lambeck *et al.* 2002). When sea levels dropped to 53 m below present, much of the Gulf of Carpentaria was drained along with the Arafura Sea in the north, creating

the Arafura Plain and Lake Carpentaria (Chivas *et al.* 2001; Jones and Torgersen 1988:323; De Deckker 2001; Torgersen *et al.* 1988).

The LGM was characterized by sustained period of reduced temperatures and precipitation throughout the Carpentarian region. This was largely due to the immense increase in the size of the continent – particularly in the north. As a consequence of depressed precipitation, widespread aridity resulted (De Deckker 2001). Lake Carpentaria was further reduced by a lack of onshore cyclones that had consistently brought rain to the interior of Sahul prior to the LGM (Webster and Streten 1978). Marine cores show that following the formation of the lake, much of the Carpentaria basin dried out with significant sand deposition due to interior aeolian winds after 40,000 years ago that peaked in dryness by 21,500 BP (De Deckker 2001). The only available permanent water within the catchment would have been the lake itself and a small number of aquifer fed rivers. It is possible that evaporation along these rivers would have greatly reduced water volumes, and that along most of the lower river courses no surface water was available.

The effect of the LGM on the vegetation was also dramatic. Previously extensive woodland areas and forests that had spread across Northern Australia were reduced to isolated pockets in inland areas and as a narrow strip along the coast along the east and south-west of the continent (Hope 1987; Hesse *et al.* 2005:57). Within the research region all vegetation communities would have contracted or reconfigured, as the impact of reduced precipitation spread north and tree cover became sparse (Figure 2.2).

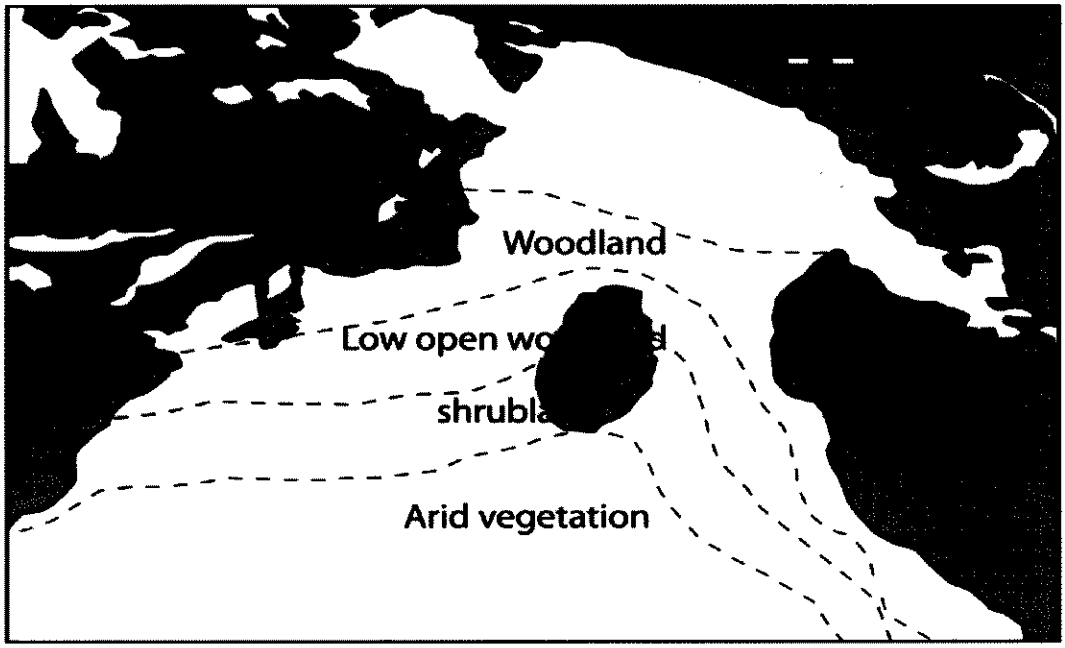

Figure 2.2: Sahul at the height of the LGM showing the northwards extension of arid vegetation communities (after Hiscock 1988).

From 23,000 BP until about 11,800 BP, the Gulf of Carpentaria was a fresh water to-brackish lake. Although substantially reduced in size during the LGM, pollen records indicate that the surrounding area was dominated by terrestrial grasses rather than truly arid vegetation (Hesse *et al.* 2004; Hesse *et al.* 2005:66). Pollen and charcoal counts indicate a cyclical wet-dry sequence which may have been seasonal even during the LGM. The overall Gulf region was characterized by a savannah-like environment with vegetation consistent with savannah grasslands and black soil plains (Torgersen *et al.* 1988:258, Figure 2.3).

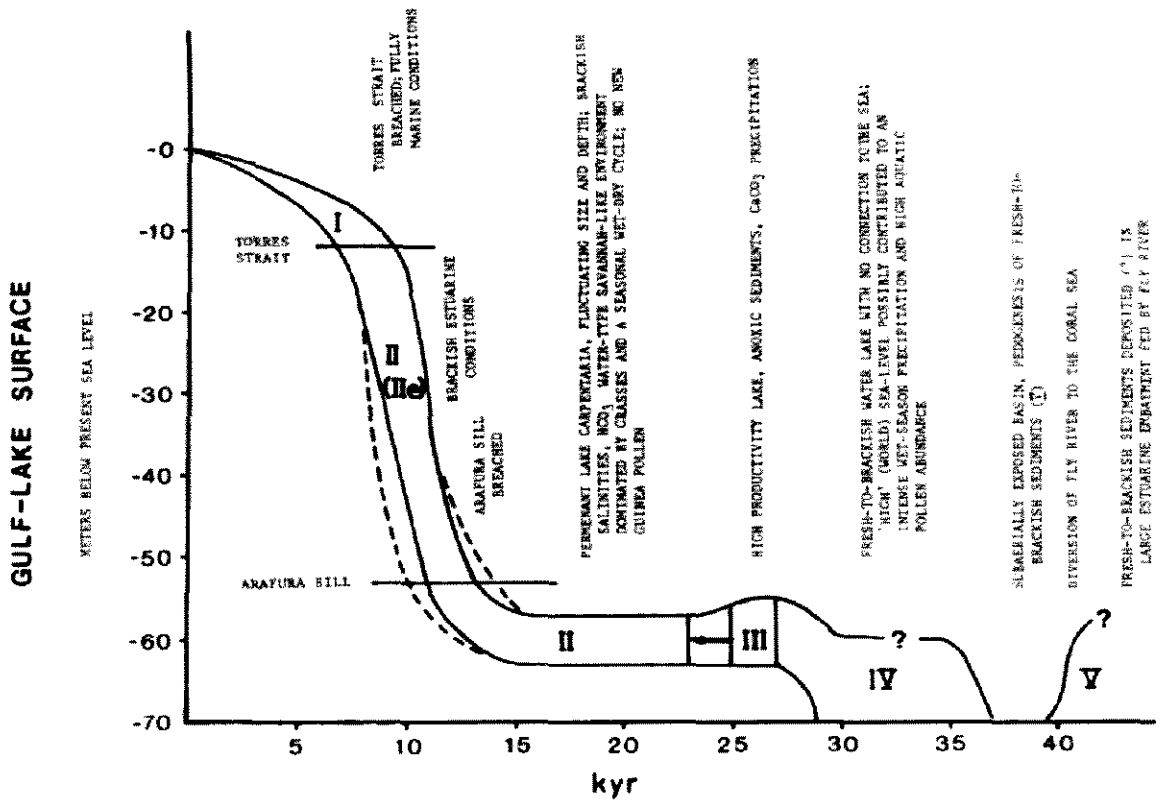

Figure 2.3: Physiographic history of the Carpentaria Basin. The Roman numerals refer to the sedimentological units of cores taken by Torgersen. Unit IIe refers to the upper stages of Unit II indicating an open connection to the sea and implying an estuarine/transitional phase during the latest sea-level rise. (from Torgersen *et al.* 1988:259)

2.2.3 Phase 3 - Terminal Pleistocene (18,000 - 10,000 BP)

Following the LGM, phase 3 was a period of large scale climatic amelioration. Average temperatures and rainfall increased as a result of glacial melting from 19,000 BP until 7,000 BP. Although the rate of global melting was initially relatively slow between 19,000 BP and 16,000 BP sea levels rose about 3.3 mm/year (Lambeck *et al.* 2002:344; Lambeck and Chappell 2001).

In many areas of northern Australia, tropical cyclones replaced cold glacial winds by about 15,000 BP (Hesse *et al.* 2004). Enhanced rainfall combined with glacial melting resulted in

sea level rises, and across the northern end of Sahul the effects were sudden. The continental shelf surrounding the Arafura plain was inundated and this rise may have resulted in a lateral flooding of up to a metre a week (Mulvaney and Kamminga 1999:121). If the estimates of rates of sea level rise of 1 – 3 m per year are correct then the effects on local flora and fauna surrounding Lake Carpentaria would have changed significantly and very quickly (Torgersen *et al.* 1983). However, Lambeck *et al.* (2002) note that during the post-LGM, sea level rises are marked by variability. Maximum rates of sea level rise are thought to have occurred between 16,000 and 12,500 BP and again between 11,500 and 9,000 BP (Lambeck *et al.* 2002:343). By about 12,000 BP sea-levels had risen sufficiently that a permanent and open connection from Lake Carpentaria to the sea had once again been established (Chivas *et al.* 2001). Salinity is considered to have remained low due to restricted water exchange and the wetter climatic conditions aided by the increased incidence of tropical cyclones.

Within the most recent of this phase (10,200–10,800 BP), a period known as the Younger Dryas is thought to occur (Lambeck *et al.* 2002:343; Edwards *et al.* 1993; Bard *et al.* 1997). It is marked by a spike of colder weather, as a notable swing back to cold and arid conditions took place for c. 600 years (Kershaw 1995; Kershaw *et al.* 1993).

Climatic change and the associated flooding of Lake Carpentaria would have had significant impacts on the environment of the study area. Enhanced seasonal rainfall and higher water levels in seasonal and permanent rivers would have driven expansion in riverine, woodland, and with shrublands replacing the arid vegetation (Figure 2.4).

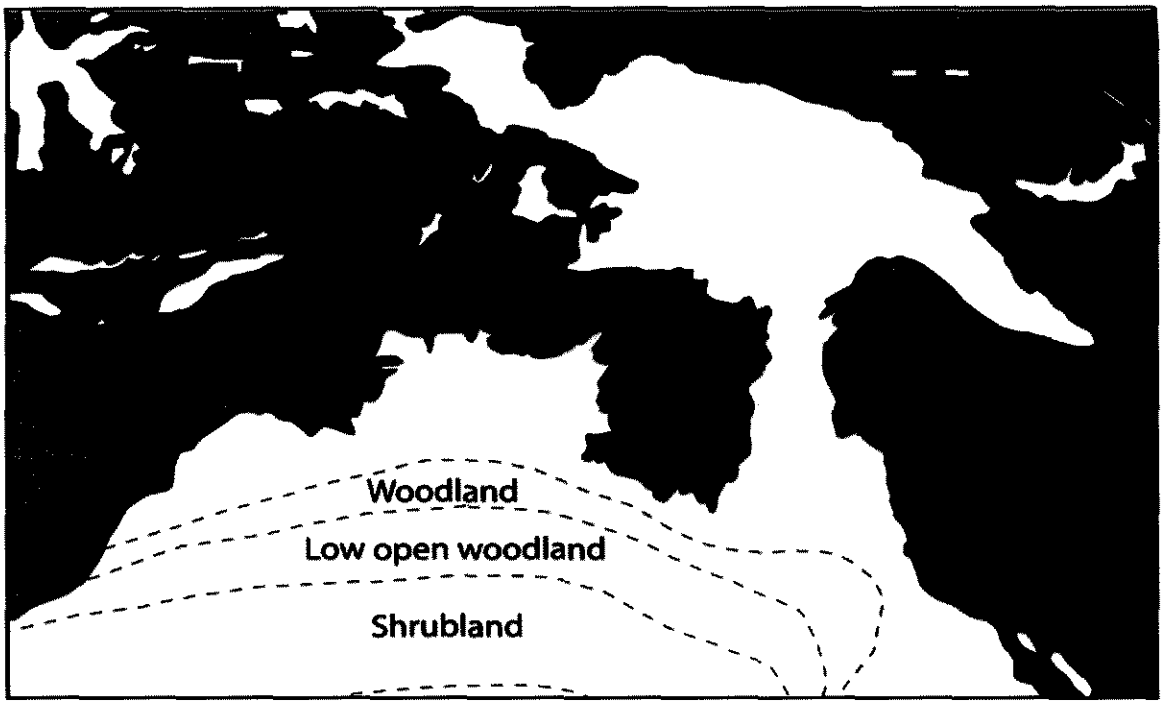

Figure 2.4: Northern Australia during the early Holocene retraction of the arid zone and expansion in shrubland and open woodlands in the study area (after Hiscock 1988).

2.2.4 Phases 4, 5, and 6 – the Holocene (10,000 BP– present)

The last 10,000 years have provided a relatively stable climate in Northern Australia when compared to previous phases, although these final three phases are dominated by two climatic events: *(i)* the Arafura Sea marine transgression through Torres Strait leading to Lake Carpentaria being transformed into one of the largest embayments in the world at approximately 9,700 BP (Chivas *et al.* 2001:19), and *(ii)* the mid Holocene El Nino Southern Oscillation event (Allan *et al.* 1996).

The first 4,500 years of the Holocene were wetter and warmer than previous phases with precipitation reaching an optimum between 8,000 BP to 5,000 BP (Gagan *et al.* 1994; Kershaw 1983, 1995; Kershaw and Nix 1989; McGlone *et al.* 1992; Nix and Kalma 1972). Towards the middle of the Holocene a general trend towards aridity occurred. Although there is extensive regional variation concerning the timing and extent of this climatic

change, it was probably triggered by the onset of enhanced El Niño/Southern Oscillation (ENSO) conditions at c. 5,000 BP. These conditions developed as the result of warmer sea surface temperatures in the Pacific Ocean, leading to increased evaporation and heating of the troposphere (Allan *et al.* 1996; Anderson 1992).

In Northern Australia, the effects of the El Nino Southern Oscillation (ENSO) have included decreasing strength in trade winds and greatly reduced precipitation, which have often ended in drought. Although the duration and configuration of ENSO is variable, it is generally believed that dry conditions have intensified over the last 5,000 years (Anderson 1992; McGlone *et al.* 1992). ENSO may have driven increased aridity later in northern Australia than in the southern temperate latitudes. Analysis of $\delta^{18}O$ records from coral and sea sediments in the Gulf of Carpentaria, and pollen records from Groote Eylandt indicate that reduction in precipitation did not occur until about 4,000-3,500 BP (Hope and Golson 1995; Kershaw 1995; McCarthy *et al.* 1996; McCarthy and Head 2001). This mid Holocene arid phase extended until approximately 2,000 BP, when the increased rainfall and warmer temperatures that are associated with the present climate commenced (Schulmeister and Lees 1992; 1995).

The effects of the mid Holocene arid phase would have significantly altered the spread of local vegetation communities. The enhanced vegetation richness along rivers and expansion of woodlands created during the early Holocene would have been substantially reduced, with less certainty of seasonal precipitation as rainfall associated with cyclones was replaced by winds from the interior (Figure 2.5). All but major rivers would have failed and resulted in a corresponding expansion of grassland communities.

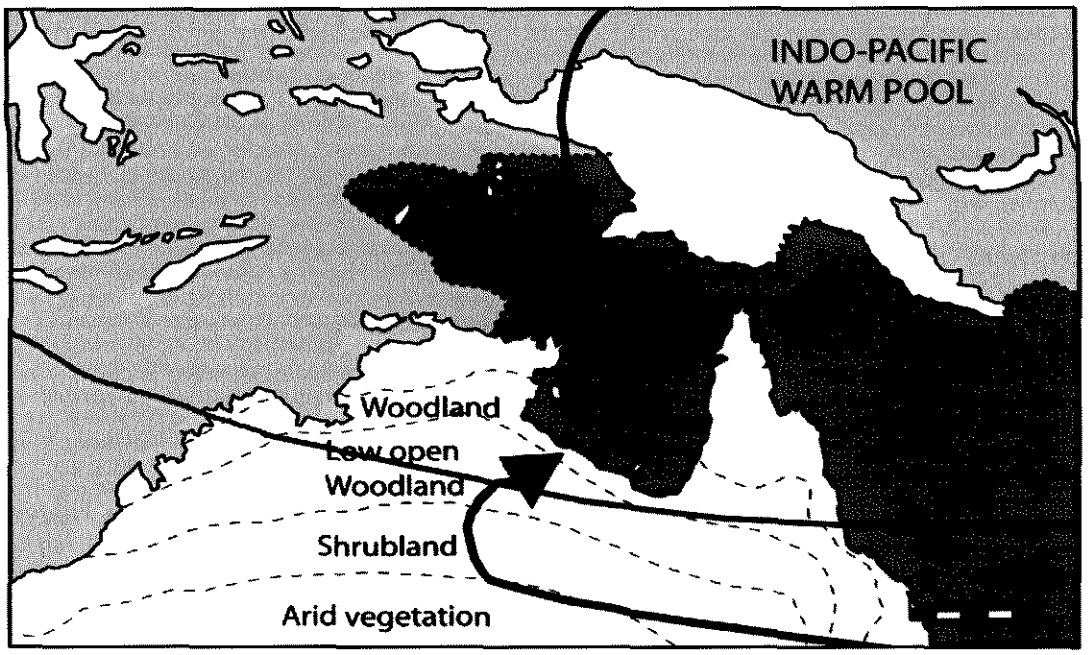

Figure 2.5: Holocene atmospheric circulation over northern Australia during the austral summer with annual mean location of ocean masses. "ITCZ' denotes Inter-Tropical Convergence Zone and 'EAC' denotes East Australian Current.

2.2.5 Summary

The substantial and sometimes dramatic changes in climate over the last 50,000 years in Australia probably played a pivotal role in the timing of settlement and the spread of hunter gatherer populations. Sea levels, water availability, and the patchiness of resources on the landscape would have all influenced how humans colonised Australia, and later arid zone settlement.

2.3 Dating the colonisation of Australia – 'the Long and the Short of It'[1]

There are many issues that affect our understanding of the timing and nature of the initial colonisation of Australia and the nature of subsequent settlement patterns. These include: *(i)* the sample number of known sites; *(ii)* complexities and uncertainties in dating techniques; *(iii)* the small number of cultural assemblages for the Pleistocene in general , and *(iv)* a lack of detailed reporting of Pleistocene sites (see O'Connor and Veth 2005).

Presently there are only fifteen archaeological sites in Australia that feature an antiquity of occupation greater than 35,000 years BP. Of these sites, four are older than 45,000 years BP, and only three have been claimed to be greater than 55,000 years old. With such a small sample of sites which are located across the continent in varying environments, no directionality of colonisation seems apparent (Hiscock and Wallis 2005). Furthermore, there is little detail available concerning the cultural material recovered at these sites, and the composition of the early occupation phase assemblages. Where published, often these assemblages are extremely small (e.g. Balme 2000) <200 artefacts and are compounded by the complexities associated with the different dating techniques applied. Numerous age determinations by the C_{14} method are approaching the limits of the technique (*c.* 40,000 years). Some very small size carbon samples have been subjected to various pre treatments and extended counting (AMS) to push this radiocarbon limit back a further few thousand years. Luminescence techniques have also been used and which whilst having limits far older than conventional dating, can suffer from problems of exposure and bleaching of sediments as well as contamination, and large error margins.

[1] Title from Allen and O'Connell 2003

2.3.1 Background

1960s to 1980s

The last 50 years has seen our understanding of the great time depth of Aboriginal occupation of Australia develop to exceed 40,000 years (see Mulvaney and Kamminga 1999). The extension of the antiquity of occupation has been accompanied by the development and application of a range of scientific techniques to Australian archaeology (most importantly the development and application of radiocarbon and luminescence dating). In the 1960s there was a general consensus amongst researchers that the human antiquity of Australia was less that 10,000 BP. However, by 1981 archaeologists were in general agreement that the antiquity was nearer to 40,000 BP (see Mulvaney 1961; O'Connell and Allen 2004:835).

O'Connell and Allen (1998:132) have suggested that until the 1990s there had been a general consensus in Australian archaeology that modern humans arrived on Australia between 35,000 and 40,000 years ago, but since that time opinions have varied considerably. In particular, during the early to mid 1990s early occupation ages were proposed for two rockshelter sites in Arnhem Land known as Malakunanja II and Nauwalabila.

Some researchers have also proposed far earlier colonisation dates but these claims have been generally dismissed or unsupported (see Fullagar *et al.* 1996; Kershaw 1976; Singh *et al.* 1981). Most archaeologists support either a short chronology, beginning *c.* 45,000 BP, or an antiquity of over 55,000 years – the 'long' chronology. As one of the aims of this thesis was to investigate the antiquity of occupation for the southern Gulf of Carpentaria region, it is worth considering this debate, particularly as it relates to northern Australia.

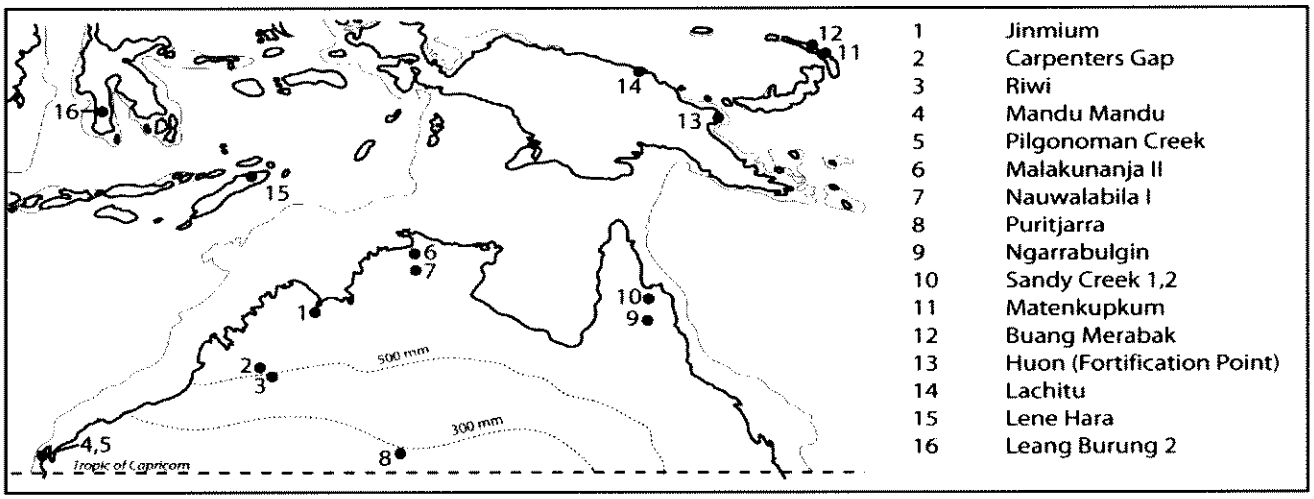

Figure 2.6: The northern Australian region showing sites with an occupation date greater than 35,000 BP mentioned in the text.

2.4 The Long Chronology

A colonisation date prior to 55,000 years BP is primarily based on evidence from three archaeological sites; Malakunanja II and Nauwalabila I in northern Australia, and from Lake Mungo in western New South Wales (Roberts *et al.* 1990, 1994; Bowler *et al.* 1970).

The Kimberley site Jinmium had also been reported as yielding much older occupation ages including artefacts associated with sediments that had been thermo-luminescence dated to between 116,000 and 176,000 years (Fullagar *et al.* 1996). If these dates were accepted, then the Jinmium data would have extended the known chronology of Aboriginal occupation of Australia by up to 135,000 years and opened up the debate on Pleistocene human evolution. Jinmium was soon dismissed due to apparent taphonomic and sampling problems, including the possibility that the dated grains may have been derived from *in situ* disintegration of sandstone rubble after burial in the deposit. Furthermore, abbreviated temperature curves of samples were possibly related to short periods of re-exposure (Roberts *et al.* 1998).

2.4.1 Archaeology in support of the long chronology

Nauwalabila I and Malakunanja II

Roberts *et al.* (1990a, 1994) have argued that the sites of Nauwalabila I and Malakunanja II contain archaeological evidence supporting an antiquity of human colonisation greater than 50,000 years for Australia. Both sites have received critical attention for a variety of reasons including; *(i)* dating techniques and interpretations, *(ii)* possible vertical displacement of artefacts, and *(iii)* contamination of samples (*e.g.* Allen and O'Connell 2003; Bowdler 1990a; Hiscock 1990; O'Connell and Allen 1998).

Nauwalabila I is a sandstone rockshelter located along Deaf Adder Creek in Kakadu National Park in northern Australia. The site was first excavated by Jo Kamminga in 1973, and re-excavated in 1981 by Rhys Jones and Ian Johnson (Jones and Johnson 1985). Excavations consisted of single 1 m^2 test pits that terminated at bedrock at approximately 286 cm below the ground surface. Stone artefacts occurred throughout 2.5 m of sandy deposit and continued into underlying sandstone rubble well below the lowest charcoal obtained from the site. An initial radiocarbon determination based on charcoal samples obtained from flotation of the 3 mm sieve residue across excavation units between 170 and 190 cm below surface returned a date of 19,975 ± 365 BP (SUA 237). In 1994, a further 14 further radiocarbon and 5 thermoluminescence dates were reported for Nauwalabila I, the lowest of these indicating that the site was first occupied between bracketed dates of 53,000 ± 5.4 ka and 60,300 ± 6.7 ka (Roberts *et al.* 1994 but also see Hiscock 1993).

O'Connell and Allen (1998, 2004) criticized the analysis and reporting of the Nauwalabila results believing the site to date to less than 40,000 years. They argue that the lowest artefacts in the site are a product of post depositional downwards displacement as a result of termite activity (O'Connell and Allen 1998:139; Allen and O'Connell 2004:15). They also provide a compelling critique of disparities between radiocarbon determinations

(including ABOX-C AMS samples), and their divergence from the OSL determinations. The latter are rejected on the basis of low palaeo-dose levels (refer to Table 7 and text in O'Connell and Allen 2004:845). O'Connell and Allen have pointed to other unresolved issues with the dating, including confusion over inversions of some dates and claimed mislabeling of samples (O'Connell and Allen 1998:135).

Malakunanja II is a small rockshelter at the foot of the western escarpment of the Arnhem land plateau about 50 km north of Nauwalabila. The site has been extensively excavated since the 1970s (Kamminga and Allen 1973; Schrire 1982; Roberts *et al.* 1990a). The deposit at Malakunanja II is comprised of 4.6 m of 'poorly sorted' sand overlying rubble (Roberts *et al.* 1990a:153). In 1990 Roberts *et al.* collected thermoluminescence samples from auger holes and excavations upon which basal occupation of the site is argued to be bracketed by TL dates of 61,000 ± 13,000 years (KTL 162) and 45,000 ± 9,000 years (KTL 164) (Roberts *et al.* 1990a:153).

Hiscock and Bowdler have argued that it is difficult to reconcile the radiocarbon and luminescence results with the cultural sequence at Malakunanja II, given the very different recovery techniques and sample recovery locations (Bowdler 1990:93; Hiscock 1990:122). Hiscock raised questions relating to the reliability of the age estimates for the stone artefacts from the site, and specifically argued that taphonomic processes, although noted by Roberts *et al.*, were not satisfactorily addressed. He also noted that there was high potential for vertical displacement of artefacts between 20,000 and 40,000 BP (Hiscock 1990:123). Roberts *et al.* (1990b:125-129; 1990c:94-97) response to both Hiscock and Bowdler's criticisms was on the basis of the validity of the TL samples and sedimentation rates, and what they saw as an implausible relationship with treadage.

O'Connell and Allen (1998:135) also point to a lack of comparative control on the TL dates greater than 24,000 years, and that sharp variation in sedimentation occurs through the crucial mid-section of the deposit. It was further noted that the radiocarbon determinations do not often match the luminescence data, and there are questions over the stratigraphic integrity of this part of the deposit [the crucial initial phases of occupation], and the association between artefacts, sediments and an observed pit feature is yet to be demonstrated (O'Connell and Allen 2004:846).

Lake Mungo

Lake Mungo is one of a series of thirteen interconnected dry lake basins known as the Willandra Lakes system, located on the Lachlan River in south western New South Wales. Erosion of lunettes associated with the lake has exposed three primary stratigraphic horizons. The lowest of these, known as Pre-Mungo, consists of soil developed on clayey sands. Overlying this layer is the Mungo unit, which is often separated into lower and upper units. The upper Mungo unit is overlain by deposits known as the Zanci unit. The various units and sub-units of sediments at Mungo have been subject to extensive dating studies over the last 20 years (see Barbetti and Allen 1973; Bowler and Thorne 1976; Bowler *et al.*, 2000; Clark 1986; Johnston 1993). Within the lower Mungo unit, two archeological sites have been recorded. The first consists of a small assemblage of stone artefacts, and the second a human burial (Allen 1972; Bowler 1970,, 1988; Bowler and Magee 2000; Bowler and Price 1998; Bowler *et al.* 1970, 2003; Shawcross and Kaye 1980; Thorne 1971, 1977; Thorne and McCumber 1972). The lower Mungo unit sediments within which archaeology was found is > 40,000 years old (Bowler and Price 1998, Bowler *et al.* 2003).

The artefact scatter site consists of eleven silcrete flakes which are bracketed by age determinations of 47,900 ± 2,400 BP and 45,700 ± 2,300 BP above and 50,100 ± 2,400

BP, 49,700 ± 2, 700 BP below (Bowler *et al.* 2003; Shawcross 2003). The association of these artefacts with the dates is questioned because of the small sample size, problematic stratigraphic relationships, and an inversion between dates and possible post depositional movement (O'Connell and Allen 2004:843).

The Mungo III site consists of a human burial located in a partly exposed context in lower Mungo sediments. Original reports state that Mungo III was in place prior to the formation of the surrounding lower Mungo sediments (Bowler *et al.* 1970). This assertion has since been rejected (Bowler *et al.* 2003) and a general consensus that the remains were about 36,000 years old ensued for some time. Recent dating studies by Thorne *et al.* however have challenged this position (Thorne *et al.* 1999).

Thorne and his colleagues published the results of uranium and electron spin resonance (ESR) analyses of the human remains and OSL determinations of surrounding sediments which were claimed to be stratigraphically equivalent to the burial (Thorne *et al.* 1999). The determinations ranged between 50,000 years and 103,000 years, and Thorne *et al.* argued for an antiquity of 62,000 ± 6,000 years (Thorne *et al.* 1999). Bowler *et al.* (2000), Gillespie (2002) and Gillespie and Roberts (2000) subsequently disputed Thorne's claims. Bowler *et al.* (2003) argue that of all the luminescence determinations that Thorne *et al* completed, only one is greater in antiquity than 52,000 years and that luminescence samples were collected from locations a few hundred metres from the burial location and are therefore of uncertain context. Grun (2006) notes that subsequent dating work by Bowler and colleagues (Bowler *et al.* 2003) has placed the age of both Mungo burials at 40 ± 2 ka (Bowler *et al.* 2003) and that when considering the entire dating data sets there is considerable overlap (Grun 2006:40). All of these issues cause O'Connell and Allen (2004:843) to conclude that "neither the M-III burial nor the local archaeological record provides solid evidence for a human presence at Lake Mungo before ca. 43 ka".

2.4.2 Summary of Long Chronology

The northern Australian sites of Malakunanja II and Nauwalabila I are problematic. If Australia was colonized by 55,000 BP as the dating studies claim, then we might also expect evidence of human occupation elsewhere in the continent at this time. O'Connell and Allen have modeled how a small first colonizing group could be expected to grow in size to high levels within just a few thousand years and have asked that given this large population why no other 'old' sites have been discovered? (O'Connell and Allen 1998:143).

Since the excavation of these sites there have been no further discoveries of localities of similar antiquity. The last 10 years has seen debate focus on the application of different dating techniques applied to these few archaeological sequences in attempts to refine or push back initial occupation dates. By 2004 O'Connell and Allen were again compelled to note that colonisation remained a contentious issue despite a lengthy period of research. Re-dating of sequences had provided little extra benefit to research. These studies had marginally extended basal occupation dates of a select number of sites and failed to significantly provide any more evidence for the "long (>60 ka) chronology" (O'Connell and Allen 2004:835, 838).

2.5 The Short Chronology

If the early dates for colonisation are rejected, we are left with a suite of twelve sites in Australia that have radiocarbon determinations between 35,000 BP and 45,000 BP (Table 1.0.1). When early human archaeological sites in Southeast Asia and New Guinea are included into the database, then a further seven sites are added. This section discusses these sites that support a 'short' colonisation model. Sites are discussed in relation to their geographic region, with a particular focus placed on locations in northern Australia, and from the arid and semi-arid zones of the continent.

site	region	environmental zone	technique	earliest date (ka)	reference
Riwi	Kimberley	semi arid - arid	14C	41.3 ± 1.02	Balme 2000
Carpenter's Gap 1	Kimberley	semi arid - arid	ABOX/AMS	40.6 ±0.8	Fifield *et al.* 2001
Cuddie Springs	Western NSW	semi arid	OSL	35.4 ± 2.8	Field and Dodson 1999
Lake Arumpo	Western NSW	arid		38.5	Clark1986
Lake Tandou	Western NSW	arid		36	Clark1986
Allen's Cave	Nullabor Plain	arid	OSL	39.8 ± 3.1	Roberts *et al.* 1996
Puritjarra	Central Australia	arid	C14	34.6 ± 1.6	Smith *et al.* 1997
Devil's Lair	SE Western Australia	temperate	ABOX/AMS	45.47 ± 1.42	Turney *et al.* 2001
Upper Swan River	SE Western Australia	temperate	C14	39.5	Pearce and Barbetti 1981
Keilor	S Victoria	temperate		38.8	Smith and Sharp 1993
Ngarrabullgan	NE Queensland	tropical	AMS, OSL	37.2	David and Dagg 1993
Warreen	SW Tasmania	temperate	C14	35	Allen 1996
Niah Cave	Borneo	tropical	C14	40	Zuraina 1982
Buang Merabak	New Britain	tropical	C14	40	Leavesley and Chappell 2004
Yombon	New Britain	tropical	C14	35.57 ± 0.48	Pavlides and Gosden 1994
Matenkupkum	New Ireland	tropical	C14	35	Chappell 2000
Lene Hara	Timor	tropical	C14	34,650 ± 0.63	O'Connor *et al.* 2002
Lachitu	New Guinea	tropical	C14	35	O'Connell and Allen 1998
Huon Peninsula	New Guinea	tropical	TL/OSL	40-53	Groube et al 1986

Table 1.0.1: Archaeological sites in Australia and Southeast Asia with basal dates greater than 35, 000 years BP excluding Mungo, Malakunanja II and Nauwalabila I.

2.5.1 Archaeology in support of the short chronology

Northwestern Australia

Two sites that pre-date 35,000 BP are located in the Kimberley region of Western Australia. Carpenter's Gap 1 and Riwi are situated well inland within an arid landscape. The antiquity of these sites points to a colonisation from island southeast Asia rather than a more northern route through New Guinea.

Carpenter's Gap

Carpenter's Gap 1 is a limestone rockshelter located in the Napier Ranges in north west Western Australia. In 1993 and 1994, five 1 m x 1 m test squares were excavated at the site. The oldest deposits were recorded from an isolated 1 m square away from the main excavations (O'Connor 1995:59). O'Connor has argued that Carpenter's Gap 1 was at the time the oldest conventionally dated site in Australia with a lowest determination of 39,700

± 1,000 BP (AMS NZA 3802) and that this date overlay further cultural material. A second date (probably the basal date) was obtained 20 cm further down the sequence and was statistically indistinguishable. O'Connor believes that this might be caused by rapid sedimentation during the earliest period of occupation (O'Connor 1995:59). Further C_{14} dates for Carpenter's Gap 1 were forthcoming, the lowest of which derived from spit 48, was 42,800 ± 1850 BP (OZD-161) (O'Connor and Fankhauser 2001). Other dates, including 33,600 ± 500 BP (ANUA-7626, ABOX 880c) from spit 45, just 7 cm above the new basal date and two dates from spit 40 of 25,390 ± 370 (ANU-11163) and 23,140 ± 620 BP (ANU-11241) were also presented (O'Connor and Fankhauser 2001).

Although O'Connor has provided compelling arguments that Carpenter's Gap 1 was occupied prior to 40,000 BP, detail concerning the nature of the assemblage itself are yet to be published. Also problematic is the unresolved issue that almost 25% of the cultural deposit is said to have accumulated at an almost instantaneous rate soon after the site was first used by people. Once the lithic assemblage is presented and association between cultural material and the radiocarbon determinations for Carpenter's Gap 1 are accepted, the site may indeed provide support for a short colonisation period post-dating 45,000 years BP.

Riwi

Approximately 200 km southeast of Carpenter's Gap is the limestone rockshelter site Riwi. Excavated in 1999, three basal radiocarbon dates were obtained of over 40,000 BP, the oldest being 41,300 ± 1020 BP (ANUA-13005) (Balme 2000:2). A stratigraphic disconformity occurs between 30,000 and 5,300 BP that is interpreted as abandonment of the site and region, coincidental with the commencement of the LGM, unsurprising given Riwi's location in the arid zone (see Hiscock and Wallis 2005).

Southeastern Australia

Inland arid and semi-arid region

Three sites with an initial occupation date greater than 35,000 BP are reported from the inland semi-arid and arid region of southeastern Australia. All are found in western New South Wales. Two sites are located in and near to the Willandra Lakes region: Lake Arumpo and Lake Tandou about 100 km to the north. Both sites consist of hearth features in association with stone artefacts within wind-blown lunettes (Clark 1987).

The third site with occupation greater than 35,000 BP is an ephemeral lake named Cuddie Springs in the northwest of the State. Excavations since 1991 by Judith Field have concentrated on an area of over 20 m^2 in the centre of the lake within which six archaeological units were identified from 1.7 m to 1 m below the surface. Both extant and extinct fauna are also known to occur *in situ* from *c.* 10 m to approximately 1 m below the surface. In the upper archaeological levels of the site human/megafauna associations are reported between *c.* 36,000 and *c.* 27,000 BP, based on both luminescence and radiocarbon methods (see Field *et al.* 2001, 2004; Wroe and Field 2006). Although the association between humans and extinct fauna is often challenged on taphonomic grounds (see Gillespie and David 2001; Roberts *et al.* 2001 but see Dodson *et al.* 1993; Field 2004; Field *et al.* 2006; Field and Dodson 1999; Trueman *et al.* 2005; Wroe and Field 2006), the basal dates of *c.* 35,000 BP are generally held as reliable, indicating that humans had definitely settled the inland of southeastern Australia by this time.

Coastal temperate and southern regions

Evidence for a pre 35,000 BP settlement date from this part of the continent is restricted to two archaeological sites. In Victoria, the site of Keilor has been dated to 38,800 BP (Gallus 1983). This date has not been generally accepted, as the nature of possibly re-deposited sediments and their association with cultural material is uncertain (see Munro

1998; Duncan 2001; Gallus 1983). The second site of Warreen is located in central Tasmania and has been dated to 35,000 BP (Allen 1996). It should also be noted that the site of Parmerpar Meethaner, has returned radiocarbon determinations of 33,260 ± 420 BP (Beta-68159) and 33,850 ± 450 BP (Beta-68159) (see Cosgrove 1995). At Parmerpar Meethaner, Cosgrove has detailed a model of hunter-gatherer settlement and subsistence behaviour that spans the LGM.

Southwestern Australia

The temperate southwest of Western Australia features two archaeological sites that date to >35,000 BP: Upper Swan and Devils Lair. Upper Swan is an open site on a floodplain bordering the Swan River near Perth (Pearce and Barbetti 1981), with a radiocarbon determination of 37,100 + 1600 - 1300 BP (SUA 1665). Devils Lair is a limestone cave in the Margaret River region of the southwest of Western Australia. It is widely accepted as the oldest conventionally (C_{14}) dated site on the continent (Balme *et al.* 1978; Dortch 1984; O'Connell and Allen 2004:840-1; Turney *et al.* 2001). This evidence comes from a hearth radiocarbon dated to 41,460 + 1,400/-1,190 BP (ANUA-11709) with associated OSL determinations of between 41,200 - 45,600 years (DL8) and 42,300 - 46,500 years (DL7) (Turney *et al.* 2001).

Central and Southern Arid Australia

Evidence of pre-35,000 BP settlement of central and southern arid Australia comes from two archaeological sites: Allen's Cave and Puritjarra rockshelter. Allen's Cave is a small rockshelter within a collapsed sinkhole on the Nullabor Plain in South Australia. First excavated in the 1960s, recent OSL dating studies of the site have produced a basal occupation age determination of 39,800 BP from sediment intermediate between a hearth and the lowest artefacts (Roberts *et al.* 1996). This same hearth has previously yielded C14 dates of 31,000 ± 1,650 BP(V82), 21,900 ± 540 BP (ANU 245), and 19,000 ± 720 BP

(V96), with little dateable material above this level (O'Connell and Allen 1998:142). There is disagreement over the nature of subsequent occupation sequences above the hearth. Initially, the sequence was interpreted as showing complete abandonment between *c.* 19,000 and 14,000 BP (Martin 1973; Wright 1971a, b). Recently others argue for continuity in occupation through the LGM (Roberts *et al.* 1996:15; Turney *et al.* 2001).

Puritjarra is a sandstone rockshelter located in the Cleland Hills approximately 300 km west of Alice Springs in the Northern Territory. The site is interesting given its location in the centre of the arid zone, in relatively close proximity to permanent water (3 km away) and being situated on the edge of an extensive area of sand ridge dune fields. Puritjarra has been argued by Smith to display evidence of "sustained occupation of the central desert from about 35,000 years ago" (Smith 2005:103).

Smith has argued that Puritjarra was occupied throughout the Pleistocene (from first occupation), including the LGM (Smith *et al.* 2001). However, the nature of this occupation was "likely to have involved multiple short-lived occupations before 35,000 years, with early establishment of populations in only a few focal areas" (Smith 2005:103-5). It is important to note however that cultural material from the Pleistocene layers represents less than 10% of the total site assemblage (Law 2003:122, 2005) and that on average, artefacts are discarded at a rate of less than 4 per 1000 years prior to 18,000 BP (Law 2003:128).

Northeastern Australia

Temperate, sub-tropical and tropical regions

Evidence of early colonisation in the northeast of Australia comes from Ngarrabullgan in far north Queensland. Ngarrabullgan is a large sandstone rockshelter located on top of a table-top mountain 18 km in length, 100 km west of Cairns in north east Australia.

Excavations at Ngarrabullgan have established a basal occupation depth at approximately 35.5 cm. The lowest radiocarbon determination for the site is from 30.8 cm below the surface and is dated to >37,170 BP (Beta-45906) (David and Dagg 1993:51). Overlying this level are finely stratified sediments comprising at least four stratigraphic units (David and Dagg 1993:51-52). Cultural material occurs in low concentrations in the lowest occupation units and high accumulation rates of cultural material occur only after 5,000 BP. David considers that Ngarrabullgan contains a number of occupational hiatuses and suggests only intermittent occupation at other times, with a major stratigraphic break immediately before 5,410 ± 60 BP (David and Dagg 1993:52; see also David *et al.* 1997).

2.5.2 Sahul: Greater Australia

When considering the colonisation of Australia, it is important to include archaeological evidence from island southeast Asia and New Guinea. These areas should be expected to offer evidence of occupation prior to the Australian dates. Other parts of Southeast Asia located farther west, are also relevant to any discussion of the colonisation of Australia, as they feature the most likely route of human migration. Seven sites greater than 35,000 years old are known for this region. Two are located on mainland New Guinea (Huon Peninsula, Lachitu), two on New Ireland (Matenkupkum, Buang Merabak), and three in Indonesia (Lene Hara on Timor, Leang Burung 2 on Sulaweisi, and Niah Cave on Borneo). At all of these sites have returned dates between 35- 45,000 BP (Allen and Gosden 1996; Barker 2002; Barker *et al.* 2005; Gilbertson *et al.* 2005; Gosden *et al.* 1991; Glover 1981; Groube *et al.* 1986; Leavesley *et al.* 2002; Leavesley and Chappell 2004; O'Connell and Allen 1998; O'Connor *et al.* 2002) (Table 5.2.1).

site	region	technique	earliest date (ka)	reference
Huon	NewGuinea	TL/OSL	40-53	Groube *et al* 1986
Lachitu	NewGuinea	C14	35	O'Connell and Allen 1998
Matenkupkum	NewIreland	C14	35	Chappell 2000
Buang Merabak	NewIreland	C14	40	Leavesly and Chappell 2004
Lene Hara	Timor	C14	34,650±0.63	O'Connor *et al.* 2002
Leang Burung2	Sulaweisi	C14	31	Glover 1981
Niah	Borneo	C14	40	Zuraina 1982

Table 5.2.1: Oldest radiocarbon dates for sites in Southeast Asia and New Guinea that have occupation dated at greater than 30,000 BP.

2.5.3 Summary

Current chronologies from C14 and luminescence dating of Australian and southeast Asian sites indicate that initial human occupation of the entire region occurred c. 45,000 - 35,000 BP. In Australia there are three sites that are dated to 55,000 - 60,000 BP. On the available evidence from the region it is difficult to accept these older dates. While publications concerning Malakunanja II and Nauwalabila I remain confined to matters of dating it is difficult to scrutinize the stratigraphic and archaeological data, and hence they will continue to remain contentious. The current dataset is consistent with a 'short' chronology of human occupation with initial settlement of Australia by 45,000 BP and the remainder of most of the continent including the interior by 35,000 BP.

2.6 Modeling Settlement

Associated with the issue of human arrival in Australia is the nature and timing of subsequent spread throughout the continent. In order to develop models of settlement, it is crucial to have confidence in individual site data. In Australia at present, the sparse dataset provides some clues to the process, but reconstructing the pattern of dispersal across the continent and the speed of this colonisation is not yet complete (see Hiscock and Wallis 2005:38). However, a number of settlement models based on archaeological evidence have been proposed. In addition, biologists have provided their own models that concern the origins and timing of dispersals into Australia based on skeletal material (see Birdsell 1949, 1967; P. Brown 1987, 1989; Pardoe 1990, 1993; Thorne 1976, 1977; Webb 1989, 1990). Recently Pardoe (1994, 2006) has proposed a unitary model of colonisation based on bio-anthropological modeling.

Three of the archaeological models for settlement of Australia are quite old, having been constructed prior to the 'revolution' in dating that accompanied research in the 1980s and 1990s (Figure 2.7). The first of these considers that rapid occupation of the entire continent took place over just a few thousand years (Birdsell 1957, 1977). The second model posits that colonisation followed the coastline, rivers and lake systems implying that settlement of the interior took place later (Bowdler 1977, 1990b). The third model proposes fluctuating occupation of different environments (Bowler 1977; Horton 1981; Jones 1979). In this model it is suggested that foragers were not restricted by a coastally adapted economy, rather they possessed a flexible economy that was more suited to inland areas (Horton 1981:23). Proponents of this model suggested that occupation of inland areas occurred soon after initial settlement but that it fluctuated during periods of climatic deterioration. In particular, during the LGM, this model suggests that large areas of the interior would have been abandoned during the height of the LGM at that time considered

to be *c.* 22,000 BP - 12,000 BP (see Horton 1981:23) or 20,000 BP and 14,000 BP (Bowler 1977:72-73). The model does not define how extensive this abandonment might have been, with Horton suggesting a movement to the coasts, whilst Bowler favoured minimal movement, suggesting relocation to better watered areas of tropical and temperate regions.

Bowdler's coastal model anticipates that the arid zone was not settled until about 12,000 BP. Any late Pleistocene sites recorded within the arid zone would constitute evidence of a 'transliterated coastal economy' that was focused on the rivers and lakes. Arid zone occupation would have only been opportunistic and temporary along a fringe, rather than a being related to permanent adaptation (Bowdler 1990b:339). As such, the discovery of continual occupation greater than 30,000 BP in areas that are truly arid and distant to water effectively refutes Bowdler's coastally adapted settlement model.

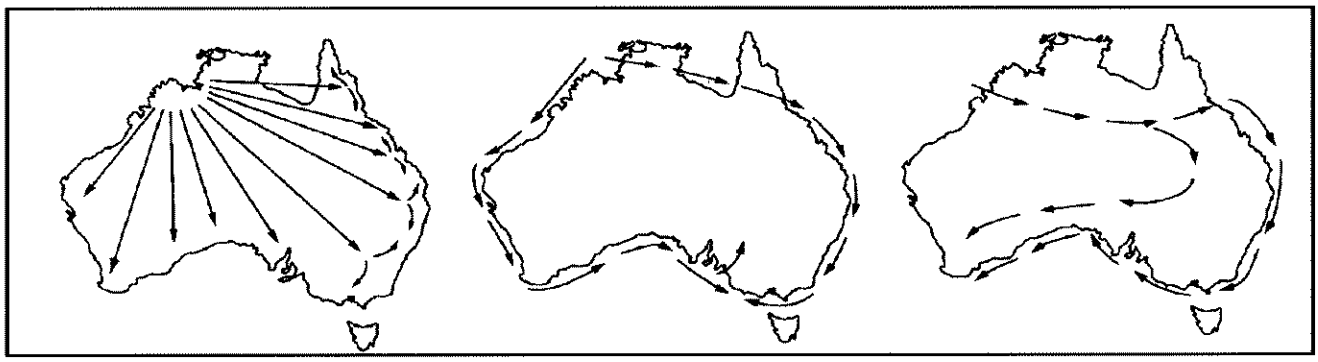

Figure 2.7: Colonisation models for Australia - (a) Rapid colonisation (b) Coastal colonisation (c) Fluctuating occupation (Flood 1983:80).

2.7 Settlement of the Australian Arid Zone

This section describes the background and development of current models that specifically describe the settlement of the Australian arid zone. It details the nature and extent of the arid zone, archaeological sites from the zone that date to the Pleistocene, and the main developments of the proposed model for arid zone settlement. The detailed arid zone

models provide a basis for appraising the merits of the more general continental models above, and at a scale greater, the pathways into Australia.

2.7.1 Deserts and Arid Areas

Recently, Veth and colleagues have noted that deserts have commonly, and incorrectly, been perceived as barriers to human settlement or as an area of transitory/temporary occupation (Veth *et al.* 2005a:1). This perspective does not accurately reflect the nature of Australian desert regions, which can be well vegetated when compared to similar locations in other parts of the world (see Hesse *et al.* 2005:56). The Australian deserts have also changed a great deal over the last 45,000 or so years that humans have occupied Australia. They are expansive areas and have, in the past contracted to far less than their current geographic spread. For example, during periods of greater aridity including the LGM, it is believed that sand dunes might have extended to most of the Australian coasts (Hesse *et al.* 2005:56) (Figure 2.8).

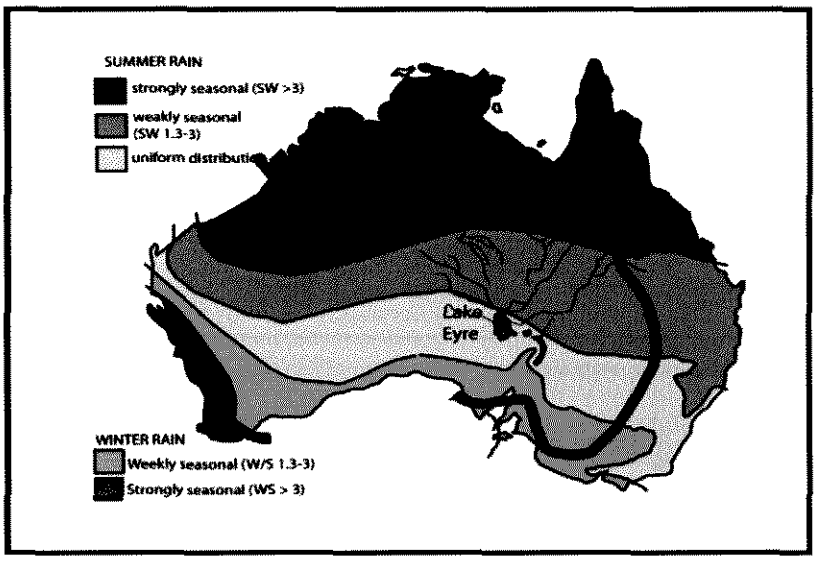

Figure 2.8 Modern Australian arid zone indicated by the areas within the thick lines, where potential evaporation exceeds actual evaporation (from Veth, Smith and Hiscock 2005:39).

2.7.2 A Background to Arid Zone Archaeology

European occupation of the northern and central arid zone occurred fairly late, relative to other parts of the continent. As a result, in areas such as the Western Desert, some Aboriginal groups were able to maintain foraging based economies and lifestyle until up to the 1950s. This has resulted in a history of anthropological and ethno-archaeological research in Australia that has targeted living hunter-gather societies and their relationship with the arid environment (see Binford 1977, 1986; Binford and O'Connell 1984; Hayden 1977, 1979; Gould 1980; O'Connell 1977, 1987; O'Connell and Hawkes 1981, 1984).

Early approaches to this research, promoted in particular by Richard Gould, stressed a uniformity in Aboriginal culture that became known as the 'Australian Desert Culture' (Gould 1980; Gould and Saggers 1985). This culture was thought to have spread across inland Australia from about 10,000 BP and had endured until recent years (Gould 1980). Gould's 'Desert Culture' model was based on ethnographic analogy, observations of Aboriginal settlement and subsistence combined with recent occupation sequences obtained at the archaeological site of Puntutjarpa (Gould 1977). This view of arid zone hunter-gatherers became a dominant paradigm for the next decade in Australia.

Following Gould's' research a resurgence in field archaeology took place during the 1980s that has had lasting effects on arid zone Australian archaeology. Three research projects were completed during this time: *(i)* in the sandy deserts of Western Australia (Veth 1989); *(ii)* in the Cleland Hills in central Australia (Smith 1988); and *(iii)* on the edge of the Barkly Tableland in Queensland (Hiscock 1988). These research projects have significantly altered conceptions of Aboriginal hunter-gatherer subsistence, highlighting much more regional and temporal variability than was previously considered (Smith 2005:226). Although numerous researchers have since contributed to the expanding archaeological picture of the arid zone (e.g. Barton 2001; Cane 1984; Gunn 1995; Law 2002, 2005; Przywolnik 2002,

2005; O'Connor 1995, 1999), debate concerning models of settlement of the region has essentially continued to be driven by Smith, Veth and Hiscock, and more recently Thorley (1998a, b, 2001). Each author provides detailed models of settlement and subsistence for inland arid Australia. After initial Pleistocene settlement from about 35,000 BP each model provides an explanatory framework for subsequent settlement, economic, technological and social histories (Smith 1988; Hiscock *n.d.* quoted in Veth 1989:81).

2.8 Models of Arid Zone Settlement

During the late 1980s and early 1990s Smith, Hiscock and Veth provided three primary models for Australian arid zone settlement that have endured until recent times. These are: *(i)* a model of continual occupation (Smith 1988), *(ii)* a model of fluctuating occupation (Hiscock 1988) and *(iii)* a bio-geographical model (Veth 1989). None of these models should be seen as entirely exclusive of the others and are largely complimentary of two recent models; *(i)* the Desert Transformation Model (Hiscock and Wallis 2005) and *(ii)* the Risk Minimising Model (Veth 2005b). All of the models agree that humans moved into Australian deserts prior to 35,000 BP and that within 5,000 years groups of hunter-gatherers were using parts of the interior from Central Australia to the Pilbara, and from Lake Mungo to the southern Kimberley region (Smith 2005:92). The differences between these models relates to human responses to different climatic conditions. These responses concern the nature of modern human behaviour and in particular adaptations to marginal environments. For example, were the first occupants generalist foragers who concentrated on riverine and lacustrine resources and then adapted technology and economy in order to survive in the deserts before colonisation, or were adaptations changes which occurred *in situ* ? (see Hiscock and Wallis 2005).

2.8.1 The Continual Occupation Model

The Continual Occupation Model has been developed by Mike Smith and is primarily based on the results of his investigations at Puritjarra. Under the Continual Occupation Model, settlement of the arid zone is considered to have occurred as the result of an initial dispersal of humans during a lactustral climatic phase that persisted until *c.* 22,000 BP. At this time freshwater sources were more common and closely spaced on the landscape (*cf.* Bowler 1976; Jones 1979). Between 22,000 and 15,000 BP, as arid conditions intensified, significant decreases in water availability caused humans to abandon lowland areas and retreat to montane/piedmont areas, but staying within the arid zone (Smith 1988:309). Reoccupation of the greater landscape did not occur until approximately 15,000 BP, and by 4,000 BP population levels had reached a correlate with the known ethnographic models (Smith 1988:310). A further arid phase between 4,000 and 2,000 BP is considered to have increased resource stress and acted as a catalyst for further reconfigurations, including changes in technology (Smith 1988:341). This in turn led to the development of seed grinding and water conservation that supported larger populations by 1,500 BP.

Recently Smith has provided further refinement to this model and has specifically rejected ideas of settlement based purely on lactustral resource exploitation (*contra* Hiscock and Wallis 2005), arguing instead that such places were resource poor, and that people preferentially targeted terrestrial dry land resources (Smith 2005:98). There are four components to this revised Continual Occupation Model: *(i)* humans colonised Australia by at least 45,000 BP; *(ii)* first movements into deserts took place between 35,000 and 45,000 BP; *(iii)* temporary climatic amelioration allowed humans to move into deserts, *(iv)* this allowed multiple short-term occupations and early establishment of populations in a few areas (Smith 2005).

Smith (2005) cites examples of five different arid landscapes that support this model: *(i)* montane and piedmont; *(ii)* sandy deserts; *(iii)* karst landscapes; *(iv)* arid littoral regions; and *(v)* riverine and lake areas (Smith 2005:102-3). Each of these landscapes is considered to have been occupied prior to the LGM. Montane and piedmont areas include the Central Australian Ranges and the Hamersley Plateau. Smith notes that archaeological sites in these regions support this argument; Puritjarra rockshelter dates from 35,000 BP, Kulpi Mara from 29,500 BP, and Newman Rockshelter in the Hamersley Range is >26,000 BP. Evidence of occupation in sandy deserts is provided by Serpents Glen at *c.* 23,600 BP; karst regions from Allen's Cave at 39,800 BP, and arid littoral regions by Mandu Mandu (34,000 BP) and Pilgonaman Creek (32,000 BP). Riverine and lake habitats at Lake Mungo date to at least 45 - 50,000 BP (Smith 2005:102-3). Most of these sites appear to display repeated use over successive millennia, particularly Puritjarra where it is suggested that sustained occupation occurred from *c.* 35,000 BP (Smith *et al.* 1997; Smith 2005:103). However, there are several inconsistencies with this model, and the nature of the archaeological record for some of these sites is contentious and demand detailed review.

2.8.2 Fluctuating Occupation Model

The Fluctuating Occupation Model proposes that occupation of the arid zone differed by local environmental region and as a response to climatic changes. People did not remain in place continually anywhere in Australia during the last 45,000 years. They moved on both local and regional scales as resource availability permitted, abandoning areas for extended periods before resettling perhaps thousands of years later. The Fluctuating Occupation Model proposes that environmental differences within both arid and semi-arid regions, and the timing of abandonment and resettlement might vary significantly on the basis of resource availability. Differences, particularly permanent water availability, are expected to

result in different settlement responses during periods of aridity. In this light Hiscock (1988) proposed that the fluctuating model might include four patterns of response during the LGM. These include: *(i)* abandonment, *(ii)* oasis occupation, *(iii)* short term visitation of arid areas by groups at nearby oases, and *(iv)* short term visits to oasis areas within arid regions from non-arid regions (see Hiscock 1988:257; Veth 1993:103-114).

In most areas of the arid zone the Fluctuating Model predicts that abandonment would have occurred during the LGM, whereas at places that featured permanent water, occupation might persist at what is termed an oasis or 'refuge' location.

Hiscock's study of two rockshelters on Colless and Louie Creeks at Lawn Hill in northwest Queensland provided the first support for the fluctuating model of human settlement (Hiscock 1988). At Lawn Hill, occupation is argued to occur first during the Late Pleistocene. During the period following the peak in aridity at 18,000 BP, humans in this region retreated into gorges (considered an oasis or refuge). Occupation of these areas persisted for the next 4,000 years until the climate ameliorated (Hiscock 1988). During this time foraging range and mobility were very low, with a focus only on the gorges. After climatic improvement, range expanded and resource exploitation in once-abandoned landscapes was then reinitiated (see Hiscock and Wallis 2005:46).

2.8.3 The Bio-geographic Model

This third model of arid settlement has three core propositions similar to the Fluctuating Occupation Model: *(i)* people maintained a presence in some parts of Australian deserts even during the height of the LGM; *(ii)* that changes in territory were a response to climate change; and *(iii)* economic and social changes continued to unfold within the arid zone during the late Holocene (Veth 1987, 1989, 1993, 1995, 2005a, 2005b; Veth *et al.* 2000).

Veth's model stemmed from fieldwork in the Rudall River region the Western Desert region of Western Australia (Veth 1989, 1993). The model provided the foundation for a broader arid zone colonisation model for Australia (Figure 2.9) (Holdaway 1995).

The model takes a bio-geographic approach to arid zone colonisation in which the timing and patterns of occupation of different regions of the arid zone are explored. The model is based on three concepts: refuges, barriers and corridors.

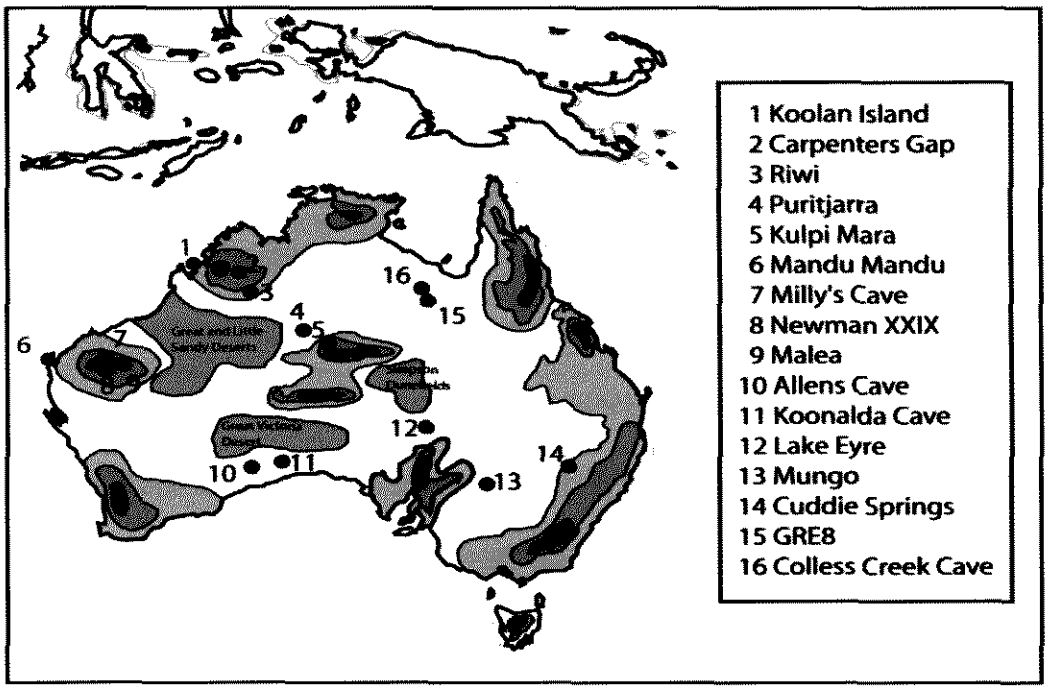

Figure 2.9 Veth's biogeographic model of refuges, corridors and barriers with sites discussed in the text (after Davey 1983). Barriers are shown in red, refuge regions in green and corridors in white.

Refuges are defined as large systems of piedmont/montane uplands and riverine/gorge systems. These areas are expected to have provided reliable water sources during all of the climatic oscillations during the last 40,000 years (Veth 1993:106). Examples of these areas include southwestern Western Australia, the Hamersley Plateau, the Kimberley region, Arnhem Land, northeast Queensland, the Murray River corridor, and eastern Victoria (Figure 2.9).

Barriers are those areas of Australia where occupation would not have been possible during periods of aridity. These areas include large sand ridge deserts and are characterised by uncoordinated and internal drainage systems (Veth 1989:81). Examples of barriers include the dune fields of the Great Sandy, Great Victoria and Simpson Deserts (see Figure 2.9). Barriers however, are not thought of as unchanging permanent features, as there have been numerous periods of formation and removal of temporary examples during the late Pleistocene. Veth's model sees these changes as a possible mechanism for connection and isolation of refuges (Veth 1989:84).

Corridors are comprised of large areas of sandy and stony lowlands. The Bio-geographical Model considers these areas to have been habitable only during climatically favourable periods, and were abandoned during the LGM as food and water resources became depleted (Veth 1989:81). Corridors would have included large tracts of land between the refuges and barriers. Occupation is expected only in the early lacustral phase of the Pleistocene and Holocene (Veth 1989:84). During periods of climatic stress corridor sites are expected to be either abandoned, or if they are in locations rich in local resources, occupied perhaps even continually, but with a shift away from regional resource acquisition to increased reliance on local foods (Veth 1989:86). As such, the Bio-geographical Model compliments that of Hiscock - Lawn Hill is a refuge in Hiscock's terms, and a 'Corridor' with sufficient resources to enable its continual occupation in Veth's terms.

The Bio-geographical Model allows for arid zone settlement during the Pleistocene prior to the LGM. During the LGM, both barrier and corridor areas were abandoned and humans retreated either to refuges or the coast. The terminal Pleistocene/early Holocene period resulted in a gradual re-colonisation of arid lands which were previously abandoned during the LGM. Over time, increases in population in these areas were associated with the emergence of regionally specific settlement and subsistence systems. From approximately

5,000 BP, specific subsistence strategies led to changes in technologies which facilitated the exploitation of seeds and hafted tools. By the mid - Holocene, extended social networks would have emerged, providing long distance reciprocity networks. Long term settlement of the arid interior eventuated in the period following the LGM (Veth 1989:90).

2.9 Recent developments in arid zone models

2.9.1 Desert Transformation Model

In a recent synthesis of the archaeology of deserts, Hiscock and Wallis proposed another model of arid zone settlement that is largely complimentary to Veths' Bio-geographic Model. Their 'Desert Transformation Model' proposes that hunter-gatherer groups did not colonise deserts. Instead people settled in inland Australia before the onset of drier conditions and maintained a presence in a rapidly changing environment (Hiscock and Wallis 2005:35). As climate changed, the dynamic nature of settlement and subsistence strategies allowed people to maintain a presence *in situ*.

Under this model greater relative availability of resources prior to 40,000 BP would have facilitated both exploration and exploitation of the interior (Hiscock and Wallis 2005:41). As such, colonisation pathways would have followed local environmental landscape features and would have been regionally specific. Hiscock and Wallis also expect that foragers had economic and social systems that were developed in response to local conditions (Hiscock and Wallis 2005:41). As aridification was more drawn out than previously thought (the Last Glacial Maximum now thought to be a period of about 12,000 years rather than a 4,000 year period) (see Lambeck *et al.* 2002), economic strategies were more likely to have evolved and been maintained over long periods. Instead of having to explain how early colonists were able to migrate into the Australian arid zone, the 'desert

transformation' model explains how deserts effectively came to people (Hiscock and Wallis 2005:42; see also Fullagar and Field 1997, Gorecki *et al.* 1997).

The lack of directionality colonisation dates for the sites that provide the oldest evidence of occupation is used in this model to propose that pre - 40,000 BP occupation was not restricted to coasts. When the climatic pressures of the LGM took hold, humans consequently altered strategies and technologies in order to maintain a presence in the landscape (Hiscock and Wallis 2005:41). In this way the model predicts that human occupation of some areas of the arid zone would have persisted during OIS2 (see Balme 2000; O'Connor *et al.* 1998), whilst other areas were abandoned, including the barriers of the sandy deserts which arose during the period of extreme aridification marking the LGM (Hiscock and Wallis 2005:45).

2.9.2 Risk Minimizing Model

Veth has recently applied a risk minimizing model to the Western Desert data (Veth 2005c). This model acknowledges the role that mobility strategies play in hunter-gatherer attempts to minimize risk during periods of environmental stress. The application of this theory to the Western Desert has explored how high residential mobility might have been coupled with low logistical mobility during the terminal Pleistocene, within an overall territorial mobility strategy where areas were abandoned for long periods of time. Veth's analysis focuses on eight different lines of evidence: *(i)* the intensity of stone artefact reduction; *(ii)* artefact diversity; *(iii)* the presence of local and exotic raw materials; *(iv)* the quantity of grinding material; *(v)* stylistic uniformity in rock - art; *(vi)* changes in sedimentary records; *(vii)* change in ochre provenance; and *(viii)* continuity in occupation of sites. The

evidence is argued to indicate that for the Western Desert, occupation during the Pleistocene was very restricted and of low intensity.

2.10 Archaeology of Arid Zone Settlement

The validity of each of the arid zone settlement models can be tested against a wealth of archaeological data available for inland Australia. Since the 1980's there has been both a growing academic and consulting archaeological interest in the arid zone. This section examines the archaeological record for the arid zone, taking a site by site approach to each of the bio-geographic zones proposed by Veth (1989), and generally accepted by others (*e.g.* Hiscock and Wallis 2005).

2.10.1 Refuge Areas

Areas termed 'refuges' often provide a central focus for discussion of both the arid zone and Pleistocene archaeology. Although many areas are proposed as potential refuge areas in Veth's Bio-geographic Model (see Figure 2.9), three regions of Australia have received detailed attention in the literature on the basis of archaeological evidence of continual occupation during periods of climatic instability. These are: *(i)* the Hamersley Plateau in the Pilbara region of Western Australia (see S. Brown 1987; Maynard 1980); *(ii)* the immediate vicinity of Puritjarra in central Australia (Smith 1988, 1989a, b); and *(iii)* Hawker Lagoon in the Flinders Ranges in South Australia (Lampert and Hughes 1988; Veth 1993:109). More recently, research has also added the area surrounding Carpenter's Gap in the Kimberley (O'Connor and Veth 2005).

The Pilbara

Hamersley Plateau

The Hamersley Plateau is an elevated area of 45,000 km² within the arid zone of the Pilbara region of Western Australia. Extensive parts of the plateau have been cut by the watershed of the Ashburton and Fortescue Rivers, and feature numerous archaeological sites including many rockshelters and caves. Owing to extensive iron ore deposits and the requirement for archaeological assessment in development processes, the area has constituted a growing focus of archaeological research over the last 30 years. Six sites are recorded as being occupied during the late Pleistocene: Yirra, Malea, Newman Rockshelter (PO2055), Mesa JJ24, Newman Orebody XXIX (PO187), and Milly's Cave (Figure 2.10).

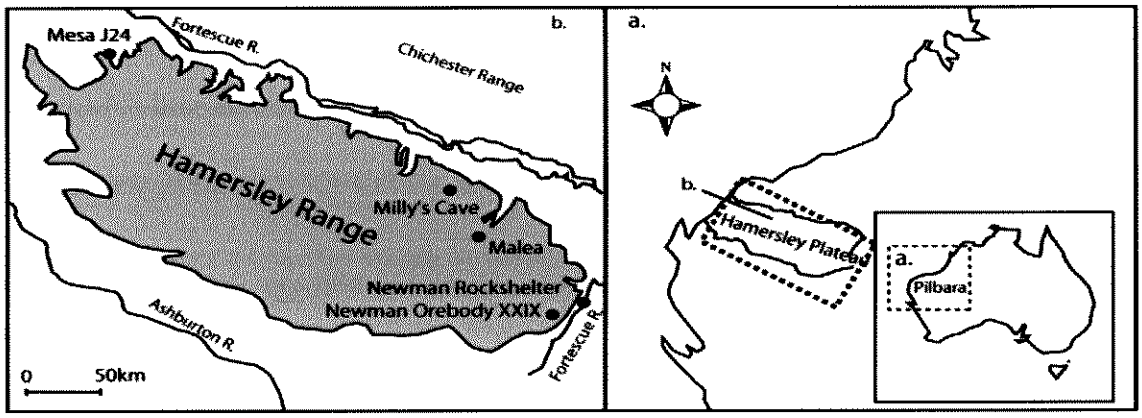

Figure 2.10 The Hamersley Plateau showing the location of sites discussed in the text.

At each of these locations arguments have been made for continual occupation throughout the LGM and the termination of the Pleistocene. At Newman Orebody XXIX (PO187) an occupation sequence commences at 20,740 ± 345 BP (SUA1041) and is considered a conservative estimate of initial use (Maynard 1980; Troilett 1982). However, there are issues concerning the validity of the interpretations of the site. Sediments between a hearth in spit 6 are dated to 9,870 ± 80 BP and a combined date from spits 8 - 10 to 20,000 BP. The exact depth of each spit is unknown, but considered to be "roughly 10 cm" (Maynard 1978:2). Both Brown and Smith have argued that the site continued to be used

during the LGM (S. Brown 1987:23; Smith 1988:305). However, the lack of stratigraphic and artefactual detail and radiocarbon dates do not negate a hiatus in occupation (Veth 1993:109).

While Newman Rockshelter (PO2055) has a basal date of 26,300 ± 500 BP (SUA-1510) (S. Brown 1987:24), there is doubt as to whether a continuity of occupation can be claimed (Comtesse 2003:120). The 26,000 BP determination comes from spit 16, whilst a radiocarbon determination from spit 10 is only 6,270 ± 210 BP (WAIT-121). Unfortunately like Newman Orebody XXIX (PO187) the depth below surface from which these samples were recovered is unknown (the rough estimate of 10 cm spits does not correlate with section diagrams which show a maximum depth of approximately 1 m). Between these two levels artefact discard is extremely low; with < 5 artefacts/1 000 years (Williams 1986:136), decreasing to zero in spit 12, and with spits 13 and 14 yielding just two flakes (S. Brown 1987:31; Comtesse 2003:30).

Rockshelter sites that have also been recorded as possible Pilbara refuge locations during the LGM include: *(i)* Yirra (Vietch and Hook 2005); *(ii)* Malea (Edwards *et al.* 2001); *(iii)* Mesa J24, and *(iv)* Milly's Cave (Marwick 2002a, 2002b). Except for Milly's Cave, all of these sites have poor chronological resolution (O'Connor and Veth 2005:38). At Malea for example, two radiocarbon determinations of 20,360 ± 320 BP (25,070 ± 520 cal BP)(Wk-3210) (97.3 - 102.1 cm depth) and 15,230 ± 230 BP (18,490 ± 250 cal BP)(Wk-3382) (72.5 - 79.6 cm depth) are overlain by a determination of just 6,570 ± 60 BP (Wk-5748) at c. 60 cm depth (Edwards *et al.* 2001:45). Although a large number of stone artefacts were recovered from the excavations, discard rates during the Pleistocene are unclear, and over 99% of the assemblage is classified as unmodified flakes and flaked pieces. It has been suggested that these flaked pieces are comprised of material that is non-diagnostic, and therefore may potentially be non-artefactual (see Hiscock 1988; Andrefsky 1998).

Neither the Yirra or Mesa J24 sites have been reported in enough detail to provide review here. At Yirra, a date of 19,270 ± 140 (Wk-8954) has been obtained from a concentration of artefacts and charcoal, and is thought to be a refuge occupation (Veitch and Hook 2005). At Mesa J24 a single date of 23,500 BP (28,380 ± 450 cal BP) (Wk-2514) has been recorded below a date of 3,950 BP (Hughes and Quartermaine 1992).

Milly's Cave features a deposit of approximately 70 cm depth that has evidence of occupation from at least 18,750 ± 460 BP (Wk-2188) (Marwick 2002:183; O'Connor and Veth 2005:39). The site appears to have been occupied periodically during the LGM when artefact discard appears to be high. However, the lowest radiocarbon determination occurs at the conclusion of the LGM and discard rates underlying this level are very low (see Marwick 2002:188). Marwick has suggested that changes in raw material discard at Milly's Cave provide evidence of a reduction in territorial range similar to that at Lawn Hill for the LGM (Marwick 2002:211-12; O'Connor and Veth 2005:40). However, as with Lawn Hill the Milly's Cave data provides more compelling evidence of occupation immediately post-dating, rather than during, the LGM.

O'Connor and Veth (2005) and Veth (2005b) have proposed a model for the Late Pleistocene occupation of the Hamersley Plateau: *(i)* human occupation persisted in uplands areas during the LGM; *(ii)* within these areas there was a territorial retraction into ranges; and *(iii)* intensity of visitation of sites is differential in relation to locally available resources (O'Connor and Veth 2005:41). There is however, no clear evidence for occupation of the region between 17,000 - 13,000 BP (Veth 2005b:137). The nature and extent of occupation in the Pilbara uplands is hotly debated (see Marwick 2002; Comtesse 2003) and at this time fails to meet Veth's requirements for refuge occupation, which includes occupation through the LGM with evidence of multiple occupation events (Veth 1989:86).

Central Australia

Puritjarra

Between 1986 and 1990 Mike Smith excavated fifteen square metres of deposit at Puritjarra, including a trench consisting of 8 m^2, from which almost 10,000 stone artefacts were recovered (Law 2003:110; Smith 2006). Smith developed a detailed chronology for the site on the basis of radiocarbon and luminescence determinations, combined with both the natural stratigraphy and a stone artefact typology.

Seven analytical units within two stratigraphic layers were identified at Puritjarra. Layer 1 represented the Holocene, and layer 2 the Pleistocene. However it should be noted that a small part of the Holocene is also represented in layer 2. Smith further divided layer 1 into 3 analytical units, and layer 2 into 4 analytical units (Table). Since Smith's study (1988) a large scale dating program has been completed and interpretations of the site have changed considerably (see Law 2003, Smith 2006).

analytical unit	age range (BP)	Smith's typological description	depth below surface
1a	0-800	late Holocene tradition	0-12cm
1b	800-3,500	post small tool tradition	12-31cm
1c	3,500-7,500	pre small tool tradition	31-43cm
2a	7,500-18,000	large flake implement tradition	43-65cm
2b	18,000-32,000	LGM horizon	65-75cm
2c	32,000	Pre-glacial surface horizon	75-81cm
2d	>32,000	early occupation horizon	81-91cm

Table 2.3: Separation of the Puritjarra deposit into analytical units based on age determinations, typologies and stratigraphy (after Law 2003).

Table 2.3

Smith has proposed that Puritjarra rockshelter provides evidence of occupation of the arid zone prior to *c.* 35, 000 BP (Smith *et al.* 2001). Following this time, changes in resource availability brought about by changes in climate, particularly during the LGM, caused changes in the territory, mobility and possibly trade of hunter – gatherers that are reflected in the use of the site. However, following his Continual Occupation Model, whilst settlement at and near Puritjarra was restricted to springs and permanent waterholes during the height of the LGM, occupation is argued to be continuous through all the different climatic periods of the last 30,000 years (Smith 1989b:93). Smith considers that particular adaptations (including the development of specialist technologies like seed grinding), were the result of human responses to increasing aridity that must have occurred *in situ* (Smith 1988, 1989a, 1989b).

Smith has argued that Puritjarra was visited continuously but with low intensity throughout the LGM (Smith 1988, 1989b, 2005). As with other continental sites, the intensity of occupation (or visitation) increased markedly during the Holocene (*cf.* Hughes and Hiscock 2004), particularly in the last 1000 years (Smith 2005:102). On the basis of the current data, rates of sediment accumulation and artefact discard during the glacial period, an alternative interpretation is also justified. Radiocarbon determinations from the main excavations in square N10 are separated by only a few centimetres, and range from 21,950 ± 270 BP from spit 11 to 12,020 ± 240 BP in spit 9 (Smith 1988: Table 4.3). A radiocarbon determination of 17,460 ± 840 BP from an adjacent trench (M11) with a "continuous presence of lithic material" is argued by Smith to provide evidence of at least intermittent occupation (Smith 1988). Smith does consider that there is less evidence of occupation during the LGM, reflecting changes in the location of activities within the site and a decline in the frequency of visitation, as it became increasingly difficult to gain access to the Cleland Hills for groups, argued by Smith to be resident in ranges to the east (Smith 1988:99).

Kulpi Mara

Very close to Puritjarra in the Palmer River catchment in Central Australia, a different picture of settlement and subsistence has been proposed. Excavations at Kulpi Mara by Thorley (1998a, b, 2001) have shown that the region was first occupied prior to 30,000 BP, then abandoned between 24,000 and 12,000 BP, whereupon occupation commenced again.

Kulpi Mara is a large sandstone rockshelter located on the eastern side of the Western Desert. It has yielded a basal occupation date of 29,510 ± 230 BP (Thorley 1998a). Between 24,000 – 12,000 BP accumulation of artefacts and sediments is very low and Thorley has suggested that a cultural hiatus occurred during this period (Thorley 2001). From 12,000 BP site usage increased and the upper layers of the site dated to 2,500 BP contain a large assemblage of flaked stone and organic items.

Thorley considers that initial occupation of this region was independent of adaptations to aridity, though the onset of the LGM forced people from the region (*cf.* Bowler 1977; contra Smith 1988). True desert adaptation occurred after 12,000 BP (Thorley 1998a:44). After this time higher artefact densities are associated with ephemeral rather than permanent water sources. Thorley interprets settlement and subsistence strategies as reflecting a trend towards smaller group size associated with general resource scarcity (Thorley 2001:1). Populations appear to have implemented risk minimizing behaviour through settlement strategies that aimed to conserve resources around permanent water, and where possible exploiting temporary sources.

Lake Eyre and Hawker Lagoon

The Lake Eyre region of arid South Australia has been proposed a Pleistocene refuge (see Smith *et al.* 1991; Veth *et al.* 1990). A number of sites including Hawker Lagoon, JSN, and two hearths near Cooper Creek have been cited as providing such evidence. Once again

there are issues with interpretations of these sites. Hughes and Hiscock (2005) point out that Hawker Lagoon is located in the semi-arid Flinders Ranges, near to permanent springs. At this site, an *in situ* industry of large artefacts dated to 18,000 BP is overlain by late Holocene assemblages (Lampert 1985; Lampert and Hughes 1988). Further research in the area has failed to record additional sites of Pleistocene antiquity (Hughes and Hiscock 2005; Lampert 1985).

The JSN site consists of a single hearth with no associated stone artefacts. Smith *et al.* have argued that radiocarbon determinations indicate that the site was used more than once between 17,500 and 11,500 BP (Smith *et al.* 1991). Finally, the Cooper Creek hearths both date to approximately 14,000 BP and are associated with stone artefacts (Veth *et al.* 1990).

Archaeological evidence of Pleistocene settlement for this region is marginal (contra Smith *et al.* 1991). The few sites that date to the Pleistocene supports the assertion that there might have been very episodic use of the arid zone in this region from the late Pleistocene (Hughes and Hiscock 2005:10).

Northwestern Australia

Carpenter's Gap

The area around Carpenter's Gap has been occupied for at least 42,000 years (O'Connor and Fankhauser 2001), though at Carpenter's Gap 1 there is little evidence for occupation between 30,000 and 11,000 BP. O'Connor and Veth have argued that after the initial occupation at Carpenter's Gap 1 evidence of occupation is sparse. A lack of cultural material is considered the result of intermittent occupation during and immediately after the LGM (O'Connor and Veth 2005:35). In fact, flaked stone artefacts decrease in number 'dramatically' from spit 16 and are found in 'negligible numbers' from spits 19 to 46

(O'Connor 1995:59). If the radiocarbon dates are compared with the few artefacts reported from spit 16 onwards, then it is more likely that Carpenter's Gap 1 features an extensive hiatus of occupation during the LGM rather than 'sparse' occupation. However, O'Connor and Veth have recently argued that occupation of the Napier Ranges and Carpenter's Gap area persisted through the LGM. This assertion is based on analysis of material from another local site (Carpenter's Gap 3) which is not yet complete (O'Connor and Veth 2005:35). They conclude that when the dates from both sites are combined they chronicle a consistent human presence in the Oscar-Napier ranges from 30,000 BP to 11,000 cal BP (O'Connor and Veth 2005:36). Stone artefacts and faunal remains are also argued to occur more frequently during the LGM at this shelter than at CG1 (O'Connor and Veth 2005:35). At this time there is no published data concerning Carpenter's Gap 3, and therefore it is difficult to evaluate these claims.

2.10.2 Corridor Areas

Five regions of Australia are considered as corridor areas: *(i)* the coastal Pilbara and Kimberley regions in Western Australia, *(ii)* the Nullabor Plain, *(iii)* inland Western Australia, and *(iv)* northwest Queensland. Why these regions constitute corridors is not usually made explicit in the literature, other than they are located between the Pleistocene coast and those areas considered refuges discussed above.

The Pilbara Coast

Along the modern Pilbara coastline there are four late Pleistocene archaeological sites that span the LGM: *(i)* Mandu Mandu, *(ii)* Pilgonaman Creek, *(iii)* Jansz and *(iv)* C99 rockshelter. These sites are small limestone rockshelters located in the Cape Range National Park, on

the North West Cape. Both Mandu Mandu and Pilgonaman Creek were excavated by Morse (1993, 1998), and the latter two sites were recently excavated by Przywolnik (2002).

At Mandu Mandu rockshelter test excavations revealed a stratified deposit extending to a depth of 80 cm. A radiocarbon determination on a carbonate nodule returned a date of 34,200 BP (Wk-1513) (Morse 1993). Morse defined two main phases of occupation separated by a temporal disconformity dated between 2,420 ± 200 (WAIT 117) and 19,500 ± 440 years BP (marine corrected date based on 20,040 ± 440 BP SUA 2614), indicating both a sedimentary and occupational hiatus for about 18,000 years (during and after the height of the Last Glacial Maximum).

Morse argues that occupation of the Pilgonaman Creek site is roughly contemporary with Mandu Mandu, with a (near) basal date of 31,770 (R1698/1). However, she notes that this early date does not date occupation, which begins about 17,410 BP (R11879/1)(Morse 1993). The same hiatus in both sediment accumulation and occupation debris recorded at Mandu Mandu is thought to persist until about 11,000 BP. At least two significant inversions in the radiocarbon determination sequence for the site have been reported (see Przywolnik 2005:184).

The two rockshelters, Jansz and C99 excavated by Przywolnik (2002), contain basal occupation dates of 35,230 BP (Wk-8919) and 33,930 BP (Wk-8925) respectively. Both sites were subsequently abandoned during the LGM - Jansz between 31,000 and 11,000 BP, and C99 at the end of the LGM between 21,000 and 8,000 BP (Przywolnik 2002:300, 2005:190). Unlike other coastal regions, the onset of the LGM did not have a significant effect on the position of the coastline relative to Cape Range. It is unclear why the area was abandoned during the LGM, although it is considered most likely that populations

might have moved to regions with more reliable resources, particularly water (Przywolnik 2005:190).

Based on the Pilbara coastal data, Veth (2005b) concludes that humans occupied the arid coast from 34,000 BP; relied on a wide variety of resources from different environmental zones and were not tethered to marine resources; and there are consistent changes in the rates of both sedimentation and material culture discard. Combined with an absence of radiocarbon determinations immediately post LGM to *c.* 12,000 BP abandonment of the site is indicated (Veth 2005b:136).

Kimberley

Veth (1993) notes that a corridor area would have featured in the Kimberley region in addition to the refuge identified around Carpenter's Gap (O'Connor and Veth 2005). There are eight archaeological sites with radiocarbon chronologies from this region that are may encompass the late Pleistocene period: Widgingarri 1, Koolan 2, High Cliffy Island, Ngurini, Bangorono, Wundalal, and Drysdale 2 and 3 (O'Connor 1995, 1999; O'Connor and Veth 2005; Veitch 1996; Walsh 2000). Of these, two are presented as evidence of corridor abandonment: Widgingarri 1 has an occupation sequence commencing at 27,610 ± 600 BP, with a cultural hiatus between 18,450 ± 1,800 BP and 7560 ± 400 BP. Similarly the Koolan 2 site appears to have been abandoned from approximately 21,000 BP until about 11,000 BP (O'Connor 1999:49, 60). It appears that for this area the local landscape, which became an inland mountain range during the height of the LGM, provided few incentives for a local population to remain in the region.

Miriwun

Miriwun rockshelter, located in the Keep River in the eastern Kimberley has been posited to document post LGM re-occupation of a Kimberley corridor (Dortch 1972, 1984;

Dortch and Roberts 1996). Initial occupation of the site occurs at 17,980 + 1,370/- 1170 BP (ANU-1008) and features abundant stone artefact and faunal assemblages through the Late Pleistocene horizons (Dortch and Roberts 1996:33). However, radiocarbon determinations from bone carbonate, obtained from similar depths within the same stratigraphic unit of the site, have provided very different determinations of 4,900 ± 850 BP (ARL-246) and 7,600 ± 700 BP (ARL-246B).

Inland Western Australia

Serpents Glen

Serpents Glen rockshelter is located on the margin of the Great Sandy Desert in inland central Western Australia is another cited example of a site located in a corridor area, positioned in a sandstone range surrounded by low relief dunes. Excavations by O'Connor have identified three primary stratigraphic layers at the site, the lowest of which has returned a radiocarbon date of 23,550 BP with a cultural hiatus shortly after this time (O'Connor *et al.* 1998). Near Serpents Glen is another site – Katampul - which also has a reported date of > 21,000 BP. There is very little cultural material above this date until reaching the upper layers of the site which date from 4,710 BP to the modern period and the upper-most layer at Katampul contains over 98% of the stone artefact assemblage. As such, there is a high probability that the site was abandoned between 20,000 BP and 5,000 BP (O'Connor and Veth 2005:37; Veth 2005b:139).

Based on the data from Riwi and Carpenter's Gap, Veth has argued that occupation of the margins of the Western Desert is of great antiquity (Veth 2005b). Occupation sequences at these sites do not continue during periods of climatic stress and the Western Desert margin

region appears to have been abandoned due to insufficient resources during the LGM (Veth 2005b:140).

The Nullabor Plain

Allen's and Koonalda Caves are located on the Nullabor Plain in South Australia and have often been discussed as offering potential evidence of early Pleistocene occupation of southern arid Australia. During the height of the LGM both sites are considered to have been either abandoned or subject to very infrequent visitation. At Allen's Cave a clear section of sterile deposit occurs between dates of 20,200 ± 1,000 BP and 11,950 ± 250 BP over a sediment depth of 50 cm (Marun 1972). At Koonalda Cave, it is argued that there was intermittent occupation between 22,000 and 15,000 BP (Wright 1971b). Recently the nature of the visitation at Koonalda has been questioned in regards to associations and dating (Roberts *et al.* 1996). A hearth dated in what is termed area 'C' has yielded problematic radiocarbon determinations of 31,000 ± 1650 (V82), 21,900 ± 540 (ANU 245), and 19,000 ± 720 (V96). It appears more likely to conclude that the site was abandoned between 19,500 and 14,000 BP and that there is a convincing argument that people were not settled in this arid region during the LGM.

Northwest Queensland

Evidence of Pleistocene human occupation of northwest Queensland focuses on Hiscock's excavations at Colless and Louie Creek Caves at Lawn Hill (Hiscock 1988). Colless Creek Cave provides evidence of settlement predating the onset of glacial conditions (probably around 30,000 BP) with a hiatus for an unknown period up to approximately 17,000 BP, whilst at Louie Creek Cave the occupation sequence commences from 17,000 BP.

According to both the Fluctuating and Bio-geographic models, the Lawn Hill region has been labeled as both a corridor and a refuge area. As a corridor area the region was expected to reflect evidence of abandonment between 20,000 until 14,000 BP (Hiscock 1988:259). However, Hiscock considered that the archaeological evidence ultimately contradicted this prediction and that it provided the basis for further refinement of the fluctuating model. He argued that the two excavated rockshelters, Colless Creek and Louie Creek, were occupied before, during and after the late Pleistocene arid period (Hiscock 1988:259). During the height of the LGM there was permanent occupation surrounding an oasis at Lawn Hill, but population densities were low and foraging territory was greatly reduced. The Lawn Hill data has shown that once the aridity of the LGM ameliorated, foraging ranges expanded once more and that the late Holocene was characterized by both extensive foraging range and associated population increases (Hiscock 1988:259).

More recently the Lawn Hill data has been cited as evidence of a 'refuge' during the LGM period (see O'Connor and Veth 2005). In reality the data actually provides compelling support for the argument that Lawn Hill was abandoned during the LGM and OIS2, rather than being a focus of human occupation.

2.10.2 Reoccupation of Corridors and first settlement of barriers

According to the Bio-geographic Model a proliferation of new sites were occupied within corridor areas shortly after the amelioration of glacial conditions, as groups that had previously occupied either refuges and/or well-watered corridor areas expanded in territory. During the late Holocene the final bio-geographic area 'barriers' were finally settled. Veth specifically uses examples of three archaeological sites to support the post LGM corridor reoccupation: Puntutjarpa, Walga Rock and Balcoracana Creek. All three

sites share similar occupation histories with basal occupation dates of 10,170 ± 230 BP, 9,950 ± 750 and 9,950 ± 2200 BP respectively (Gould 1977; Bordes *et al.* 1983; Lampert and Hughes 1988). Additional new sites including Cuckadoo 1 located near Cloncurry in northwest Queensland, yielded a near basal date of 15,270 ± 210 BP (Sutton in Veth 1989:87), and JSN located in the Strezlecki dunefields which has been dated to 13,850 ± 190 BP (Smith *et al.* 1991; Wasson 1983) are cited by Veth to indicate this settlement expansion.

According to Veth's model, occupation of barrier regions including sandy desert areas occurred last of all, during the mid Holocene, as a result of increasing population levels resulting in a range of economic and social transformations (Veth 1993:111). Sites excavated by Veth in the Rudall River region of the Little/Great Sandy Desert were used to test this assertion and included: Jalpiyari, Karlamilyi, Winakurijuna, Karlamilyi and Yulpul. All sites dated to the mid Holocene, with Therreyerte in the Simpson Desert also dating to 3,040 BP (Smith 1988:269; Veth 1989:89).

2.11 Conclusions

This chapter has examined the evidence and issues surrounding the timing and routes that humans took into Australia and their subsequent migration into the arid zone. The dominant models of arid zone settlement have been discussed. It is clear that there are substantive problems with each model that the archaeology of Australia's Pleistocene must resolve. Three crucial issues concern the colonisation of Australia and settlement of the arid zone. Firstly, the age estimates are broad, with TL and OSL dates having 68% confidence limits error margins can be potentially up to 10,000 years. Secondly, there is a lack of systematic sampling of the continental record. Identification of one old

archaeological deposit in any region should be regarded as a minimum antiquity for that area (see Hiscock and Wallis 2005:36). Thirdly, there is a deficiency of detailed discussion of taphonomic/formational processes for almost every deposit cited in discussions of these issues (see also O'Connor and Veth 2005).

Veth has observed that developing a model for the settlement of the Australian interior has been a matter of "the filling-in of great blanks on the archaeological map, once survey and excavation has begun to explore them" (Veth 1995). Excavations by Veth in the Western Desert, Hiscock at Lawn Hill, O'Connor at Carpenters Gap and Smith at Puritjarra have only just started to build the explanatory frameworks for this transitional story. Given the enormity of the Australian continent, further excavations and detailed regional studies are required.

Given the proximity of the Riversleigh and Lawn Hill research area to both possible colonisation routes and to the interior, the issues of colonisation and arid zone settlement models are of central concern. The following chapters now turn to a more detailed presentation of the Lawn Hill data and the development of a regional settlement model that is complementary to the risk minimizing model described.

Chapter 3

Lawn Hill and the Pleistocene Settlement of the Gulf/Lake Carpentaria and Australia's Arid Interior

3.1 Introduction

This chapter reviews the contribution of Peter Hiscock to the issues of the settlement of the Australian arid zone and 'refuge' models, specifically in relation to his research in northwest Queensland. The chapter presents Hiscock's model of arid and semi-arid human settlement. Hiscock's PhD research focused on the Lawn Hill region, which is within the present study area (see Figure 3.1), and involved survey, and subsequent excavation of numerous archaeological sites. Detailed analysis of the flaked stone assemblages from these sites formed the basis of Hiscock's model of settlement and subsistence activities for the region.

3.2.1 Background – Interest in the region

During the late 1970s and early 1980s the southwestern region of the Gulf of Carpentaria attracted its first scientific attention by those interested in inland tropical Australia (Aplin n.d.; Hiscock 1984a, 1984b; Hughes 1983; Hughes and Lampert 1980; Morwood 1979, 1981). Further interest developed following archaeological excavations at Colless Creek Cave on Colless Creek (a tributary of Lawn Hill Creek), which yielded an initial occupation date of *c* 17,500 BP (Hughes 1980). Over 200,000 stone artefacts were recovered from 4 contiguous 50 cm x 50 cm test pits (Hughes n.d.). Hughes argued that the initial occupation of Colless Creek cave was at least 30,000 BP and might have been much older (Hughes 1980).

The site drew widespread interest, with Hiscock employed in *c.* 1980 to examine the stone artefacts from the site. A further reconnaissance field trip by Hughes, Hiscock, Morwood

and others along the O'Shannassy River was completed, but no publications or reports were generated (Hiscock and Hughes 1984). At the time, plans were made to survey the length of the Gregory River, although it appears that such a fieldtrip never occurred, and after 1980, archaeological investigations of the region were concentrated at Lawn Hill by Hiscock.

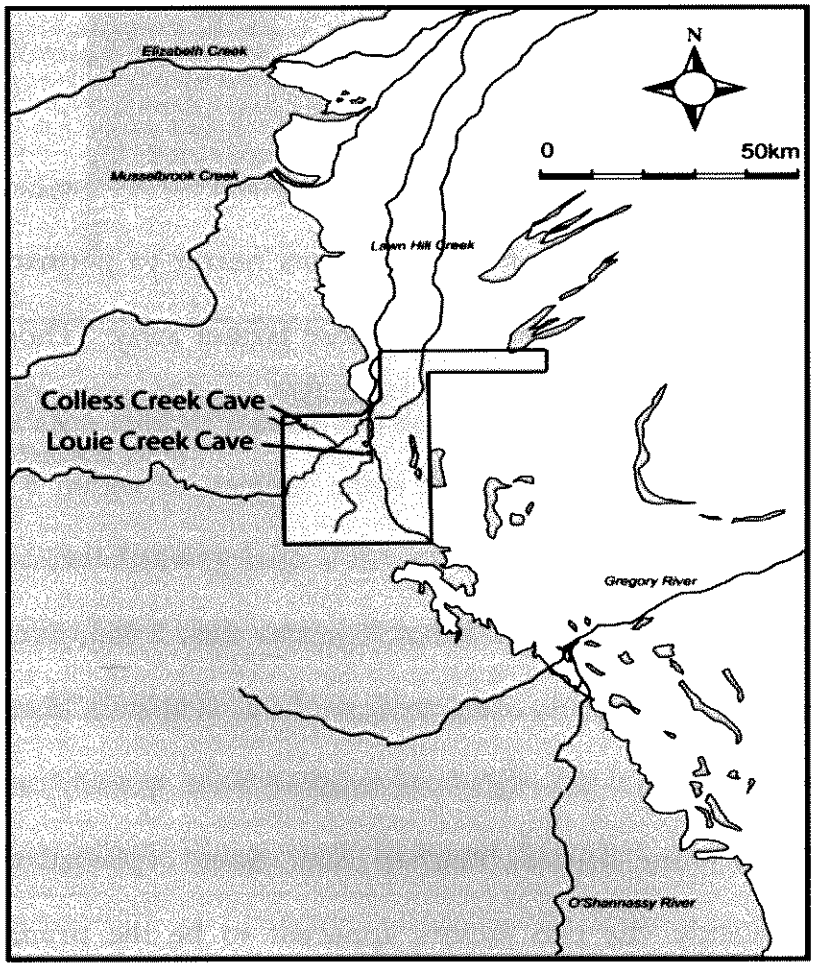

Figure 3.1: Hiscock's study location at Lawn Hill, northwest Queensland showing the survey area in yellow and the locations of Colless Creek and Louie Creek caves.

3.3 Hiscock's Doctoral Research

The aims of Hiscock's PhD research were to examine the nature of material culture at Lawn Hill with particular reference to the manufacture and transport of flaked stone artefacts, stone raw material procurement strategies and developing technological approaches to explanations of assemblage variation (Hiscock 1988:2). One of the

underlying aims of the study was to reconstruct how changes in material culture reflected responses to environmental changes, achieved through analysis of the location of activities, especially procurement and discard (Hiscock 1988:3). Hiscock's research consisted of two main elements: an initial detailed survey of the region, and excavation of a number of selected sites.

3.4 Survey

Hiscock's survey consisted of fifty-eight 1 km^2 units spread across the Lawn Hill study area (Figure 3.2). In summary Hiscock found that units nearer to permanent water and to quarries more frequently contained sites than those farther away. Those units closest to quarries contained the maximum density of flaked stone artefacts. Over 80% of all sites in the study area were located within 3 km of stone sources, or within 3 km of permanent water, sites were within 3 km of either water or a quarry, with almost all sites occurring within 200 m of these features. At a distance greater than 2 km, overall rates of stone discard dropped substantially but no consistent trend was evident in distance-decay curves. Hiscock's surveys revealed that although stone artefacts were spatially associated with both permanent water and stone sources, neither taken alone explained the nature of the relationship. Importantly, the two factors appeared to be the primary environmental determinants of artefact discard (Hiscock 1988:83).

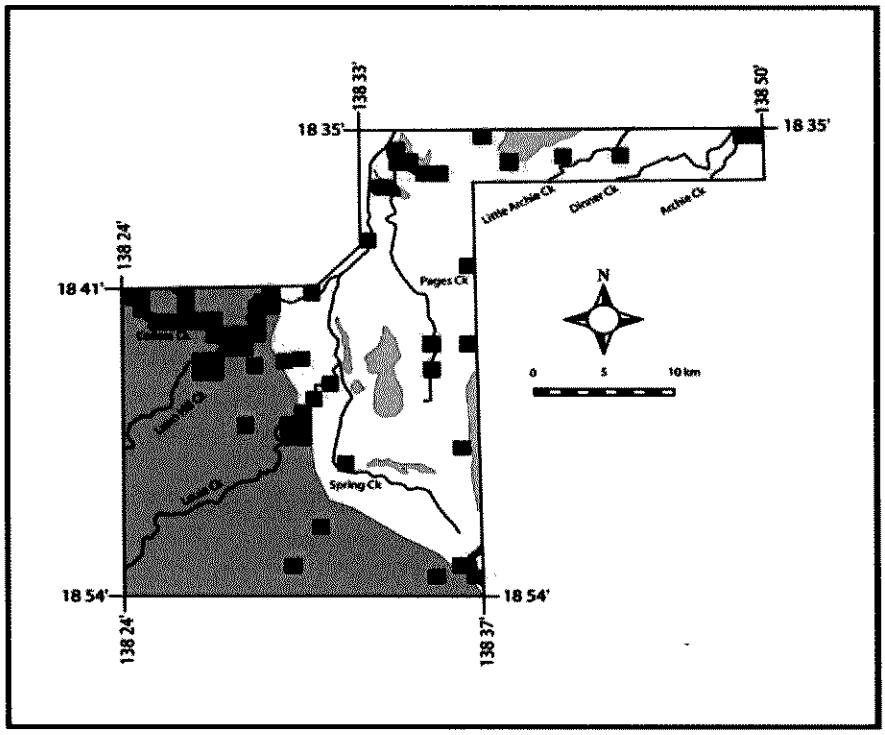

Figure 3.2: Hiscock's survey of Lawn Hill. Each 1 km² surveyed unit is shown in red. Dark grey shaded areas indicate plateau, and lighter shaded areas indicate mesas and sandstone hills (Hiscock 1988).

Hiscock concluded that the trends in stone artefact discard near quarries was most likely the result of occasional use over extended periods that "created an abundance of debris relative to activities of similar duration at other parts of the landscape" (Hiscock 1988:84). High artefact discard near to water is argued to be the result of activity locations centering on water, where material was transported, used, and discarded.

Hiscock also suggested that the way in which the landscape was used, that is the intensity of activities across the landscape, was differential. Secondary factors including seasonal water and shelter were found to influence artefact discard. Sheltered sites on rocky outcrops with extensive views across the landscape displayed higher discard densities than other locations, and the same was true of areas close to seasonal water and caves.

Along the river corridors differential rates of discard were also found. Areas on levee banks displayed higher concentrations than other areas. A variety of taphonomic explanations are offered for these trends including, hunter-gatherer preferences for flat

areas and finer sediments, the presence of trees providing shade, and food resource locations (Hiscock 1988:87). It was also suggested that there was probably greater sediment deposition on lower creek banks due to flooding that had effectively masked any discard by burial of archaeological material.

Survey revealed that the geology of some areas - most notably the gorge systems of Lawn Hill and Colless Creeks - included numerous caves, rockshelters and fissures. These features displayed evidence that they had been extensively used by humans; with the major determinant for such site use being available floor size. Floor area was recorded for 88 potentially habitable sites and was found to be > 14 m^2 with an average volume of 30 - 45 m^3 for all sites with evidence of occupation (Hiscock 1988:89).

Stone artefact reduction

The main focus of Hiscock's survey was to examine the nature of reduction sequences across the landscape. A non-uniform reduction sequence was found between sites; however some general attributes were noted for the different stone raw materials available. The geology of the Lawn Hill region is such that the location of stone material suitable for knapping is highly predictable. For example, the sandstones of the Constance and Termite formations commonly occur as grindstones and other site furniture on the surface of many rockshelters and caves, and open sites in the region. Flaked stone artefacts are most commonly made from two types of rock; chert and greywacke (Hiscock 1988:50).

Chert

Chert is found at two locations in the region: Mount Jennifer and the Barkly Plateau, and within the Thorntonia limestone at Lawn Hill and Riversleigh. Whilst there is abundant chert surface rubble in the form of pebbles at Mount Jennifer, Hiscock found that the incipient fracture planes of this material made them unsuitable for knapping (Hiscock

1988:51). As such, the Cambrian dolomites of the Barkly Plateau and the Thorntonia limestone represent the only sources of this material. Within the dolomites, chert occurs in two forms: *(i)* exposures in the parent limestone running in thin bands (Figure 3.3), or *(ii)* rounded nodules (up to 15 cm in diameter), cobbles and gravels in the beds of watercourses. Hiscock differentiated between two types of chert labeling them Q-chert (quarried) and R-chert (river), using a number of attributes. These are detailed in Table 3.1 below.

attribute	r - chert	q - chert
shape	angular and often cuboid	spheroid
cortex	thin and smooth	surrounded by dolomite
	distinctive red and yellow suggesting oxidisation	weathers to become grey or black
		rough and rilled
fracture	smoother more lustrous surfaces	greater effort to remove flakes
	distinct banding	ventral surfaces are rougher
	much greater variance in fracture quality	
colour	wide range from white to yellow and blue to black	white to grey throughout
	often banded	

Table 3.1: Attributes of quarried and river cherts at Lawn Hill, northwest Queensland (after Hiscock 1988:51-2).

Of the two types of chert, the cobbles from rivers are by far the better raw material for knapping. Quarried material with a thicker and softer cortex transmits force poorly and does not produce platforms conducive to knapping, whilst river chert, with its thin and hard cortex, transmits force particularly well.

Figure 3.3: Chert occurring in a limestone band near Colless Creek, Lawn Hill, northwest Queensland.

Greywacke

Greywacke is the term used to describe a range of materials ranging from silty greywacke to tuffaceous siltstone. These materials are all derived from the same lithological unit (Pmh4 member of the Lawn Hill formation). The term greywacke was used to describe all occurrences of this raw material (Hiscock 1988:53). Hiscock established that all known outcrops of greywacke of flaking quality were located in the northern areas of Lawn Hill at Edith Springs, Mount Jennifer and Hartness Springs.

Greywacke can be generally described as having a mottled green-grey or blue-grey appearance with a dull and rough grey-cream vesiculated surface cortex. It often features small inclusions of sericite flakes and quartz crystals set within fine chalcedonic matrixes. The fracture properties of greywacke are generally good but are subject to control by well

formed and weathered cracks. When the fracture plane passes across such cracks the direction of fracture is altered and step terminations are likely.

Suitable greywacke for use as flaking stone occurs as cobbles, boulders, and angular slabs. Within greywacke outcrops, cobble size was relatively uniform, but varied considerably between sources: 5,337 cm^3 at Pages Creek, and 215 cm^3 at Dinner Creek (Hiscock 1988:53).

Tensile and compressive strength of greywacke is far lower than that of chert. While less force is necessary to initiate fractures, the material is less easy to control. Hiscock determined that these attributes suited production of large, thick flakes and that the potential use-life of artefacts made from greywacke would be substantially less than those made from chert (Hiscock 1988:54).

Figure 3.4: Photograph of greywacke outcropping on a spinifex hill at LH9, Riversleigh, northwest Queensland.

Other raw materials

Whilst chert and greywacke dominate stone raw materials suitable for flaking, the other minor components are comprised of silcrete, quartzite and metadolerite. Silcrete is described as quartz grains set within a crypto-crystalline matrix. The lateritic duracrusts of mesa formations along Mussellbrook Creek are the most likely silcrete sources in the region. Quartzite of flakeable quality outcrops as fractured blocks of blue-green stone on the Ploughed Mountain formation to the east of Lawn Hill (see Hiscock 1988:54).

Edge ground implements produced from metadolerite occur at Lawn Hill although no suitable raw material sources are known in the region. This material may have been transported from quarry sites to the south east and possibly as far away as Lake Moondarra at Mount Isa, 250 km south east of the research region (J. Allen pers. comm. 2005; Hiscock 1988:54-5; Hiscock and Mitchell 1993; Tibbett 2001, 2003).

3.4.1 Survey results

Of the stone raw materials available at Lawn Hill, chert and greywacke dominate the archaeological assemblages. The overall morphology of raw material nodules appeared to be a critical factor in reduction. Hiscock noted that chert nodules were mostly between 100 – 250 cm^3, and that all were less than 400 cm^3 (Hiscock 1988:153). Nodules which were angular with a thin cortex were often struck on the natural surface with no prior platform preparation. Where cortex was thicker, platform preparation occurred. For example, chert that had been quarried rather than obtained from river cobbles was often spherical and had thick cortex that required platform preparation (Hiscock 1988:155). Quarried chert cores were generally reduced by rotation, with minimal initial reduction (an average of 8 flakes removed). Reduction of quarried chert initially aimed only to remove cortex, and many these cores were not transported far from their source.

In contrast, the reduction of chert cobbles obtained from creeks (R-chert) was often undertaken with no core rotation. Hiscock found that R-chert featured prominently on the plains, and that the initial stages of reduction took place at gravel banks within the riverine areas at sources. Initially, ten flakes on average were struck from chert cores. Reduction was often aimed at producing large broad flakes with pronounced bulbs. Such flakes were often used for tula adze manufacture. At one site, LC2, Hiscock found that some of these flakes had been retouched in a burin-like way, with the removed spalls used to manufacture backed artefacts. River cobble chert cores were also transported some distance onto the plains. With increasing distance northwards and away from sources, a greater amount of core rotation was noted.

Greywacke reduction was markedly different to that of chert, primarily due to the size of nodules and raw material qualities. On the plains, greywacke boulders size up to 5,000 cm^3 were reduced by removal of between 70 to 100 flakes (chert flake removal was generally between 30 and 50). Often greywacke was heat treated late in the reduction sequence and immediately prior to retouching flakes. No evidence of bipolar flaking was found with greywacke, whereas chert flakes were sometimes struck using this technique (Hiscock 1988:157).

Different raw materials were used for particular artefact types and inferred uses. Chert, with a very fine grain and strong tensile strength is the only raw material used for artefacts where maintainability was of concern. Artefact types such as backed artefacts, tulas and scrapers are only known on chert from this region. Greywacke, in contrast, is of less tensile strength, coarser grain but available in larger nodules and was favoured for point production (Hiscock 1988:160).

With a model of flaked stone artefact discard and reduction formulated for the study area, Hiscock then excavated a number of archaeological sites: including two open midden sites, and two rockshelter sites, Colless Creek Cave and Louie Creek Cave.

3.5 Excavations

3.5.1 Colless Creek Cave

Location and background

Colless Creek Cave (Figure 3.5) is located on a small permanent tributary of Lawn Hill Creek, approximately 7 km from the eastern edge of the Barkly plateau. The entrance to the cave is *c.* 5 m above the creek at the top of a steep scree slope and the immediately below a 15 m vertical cliff. The cave is a limestone cavern that is 7 m wide, 2 m high and extends 12 m into the dolomite cliff face. The floor of the cave has a thin veneer of gravel and artefacts and features several large boulders of roof fall. The cave floor slopes down from the rear of the shelter to the front and from left to right. Water flow as a result of wet season storms runs along the south wall, where lags of gravel and artefacts are common.

Above the cave is a plateau that consists of dissected flat-topped hills and vertical gullies with outcrops of dissected dolomite. There is no water on the plateau and about 70% of the ground is bare rock. Close to Colless Creek cave is a natural outcrop of Q-chert (site CC2) which has been extensively quarried, and two archaeological sites containing an abundance of sandstone grindstones (Hiscock 1988:164).

Within the Colless Creek Gorge there are several permanent pools of water containing fish, turtle, crocodile, shellfish, and numerous edible plants. The gorge is approximately 160 m wide, within which is found a diverse vegetation community including woodlands, grasses,

fringing vegetation, and remnant species including *Livistonia sp.* and cycad. Faunal species found here are less numerous within the gorge than on the adjacent plateau, and include small macropods, possums, echidnas, and bats. A gravel bank immediately outside the cave contains nodules of R-chert.

Figure 3.5: Colless Creek showing the limestone gorge and vegetation adjacent to the creek, Lawn Hill, northwest Queensland.

There are at least thirty known rock-art sites along Colless Creek (Walsh 1982, 1985; Border 1989; Slack 2002). Freehand painting accounts for almost all the motifs with a few abraded engravings and a couple of hand stencils (Walsh 1982:4). Most of the motifs in the gorge are schematized with smaller groups of figurative motifs consisting of bird tracks, human figures, snakes and boomerangs, almost all of which are mono-chrome. One humanoid consists of a polychrome figure in-filled with black, with decorative red internal lines and a perimeter white outline. Abrasion techniques have also been often used to enhance the outline of some older motifs. The art of the gorge seems to contain elements of the first and oldest (6) phases of art styles (Walsh 1982; Border 1989).

Excavations

The 1979 excavations of Hughes and Aplin consisted of four 50 cm x 50 cm test pits, two of these to the rear of the shelter (P46 and Q46) and two near the front (T39 and U39) (see Figure 3.6 below). Hiscock's subsequent 1982 investigations involved excavation of a further ten 50 cm x 50 cm squares around the Hughes and Aplin test pits at the front of the site (see Figure 3.6 below). Surface artefacts were also collected from a further four squares within the cave and 66 squares on the scree-slope. Ten test pits were excavated by spits an average of 1.5 - 2 cm in depth and sieved through 6 mm and 2 mm paired mesh.

Figure 3.6: Plan of Colless Creek Cave showing excavated squares, Lawn Hill, northwest Queensland. Square P46 which was used by Hiscock for lithic analysis is shown in red (from Hiscock 1988:599).

Stratigraphy

The stratigraphic sequence of Colless Creek Cave consists of two distinct horizons separated by a gravel lag deposit. The upper layer (Unit A) consists of a dolomite gravel derived from roof fall and a sandy matrix of pedorelicts of calcareous clay and quartz

grains. The lower unit (Unit B) consists of a reddish brown dolomite gravel and secondary carbonates. The sediment of Unit B is argued to be similar to that of Unit A, but subject to a long period of *in situ* weathering. Most of the Colless Creek sediments have entered the site through fissures in the rear of the cave (Hughes 1983:60).

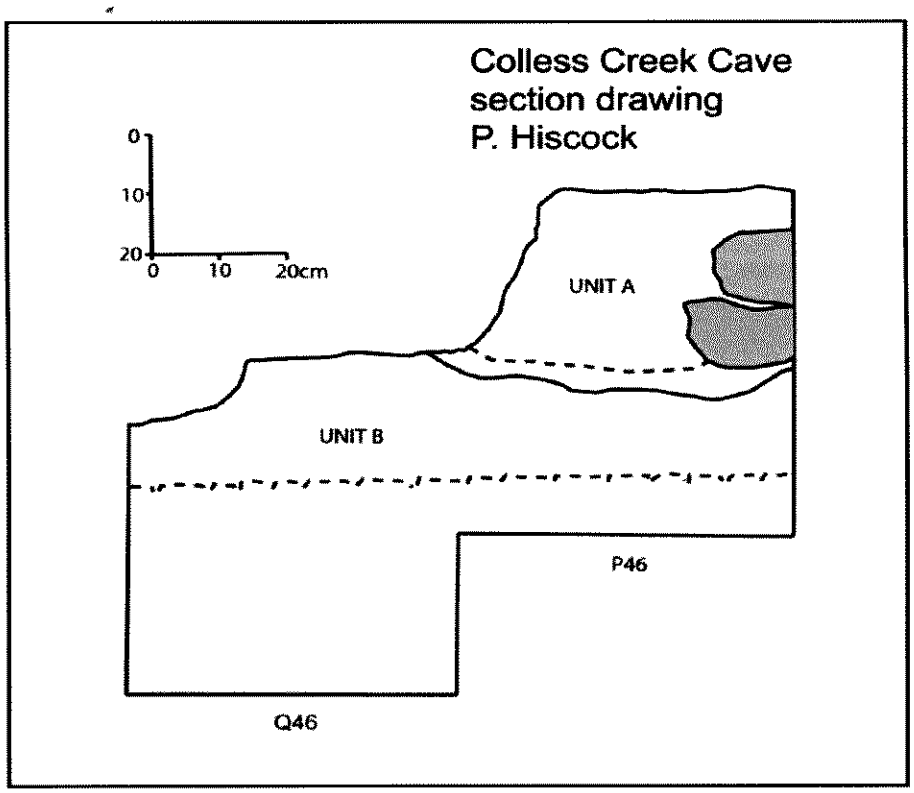

Figure 3.7: Section profile of square P46 at Colless Creek Cave, Lawn Hill, northwest Queensland (after Hiscock and Hughes 1984:12).

Chronology

Dating of the deposit was completed using radiocarbon determinations on freshwater mussel shell from Unit A, with no dateable material recovered from the Unit B deposit. A sample of living mussel shell was also submitted by Hiscock for analysis to investigate possible reservoir/secondary carbonate contamination of shell samples. If secondary carbonates were present then the living sample would be expected to return a radiocarbon date much older than its actual death age. The determination on this sample of 99.3 ± 1.0% (ANU 2444) showed that dating this material was unproblematic (Magee and Hughes 1982). Further testing of the mussel shell using x-ray diffraction did not show any

evidence of carbonate re-crystallization (Hiscock 1988:168).

Six radiocarbon determinations were obtained for the Colless Creek deposit from spits 2, 5, 8, and 10 of square P46, and samples from squares U39, T39. An age - depth curve was only possible for square P46. In T39 and U39 considerable time-span with little associated deposition (only 15 cm) precluded the construction of an age - depth curve. The results of radiocarbon determinations for square P46 are shown in Figure 3.8 below.

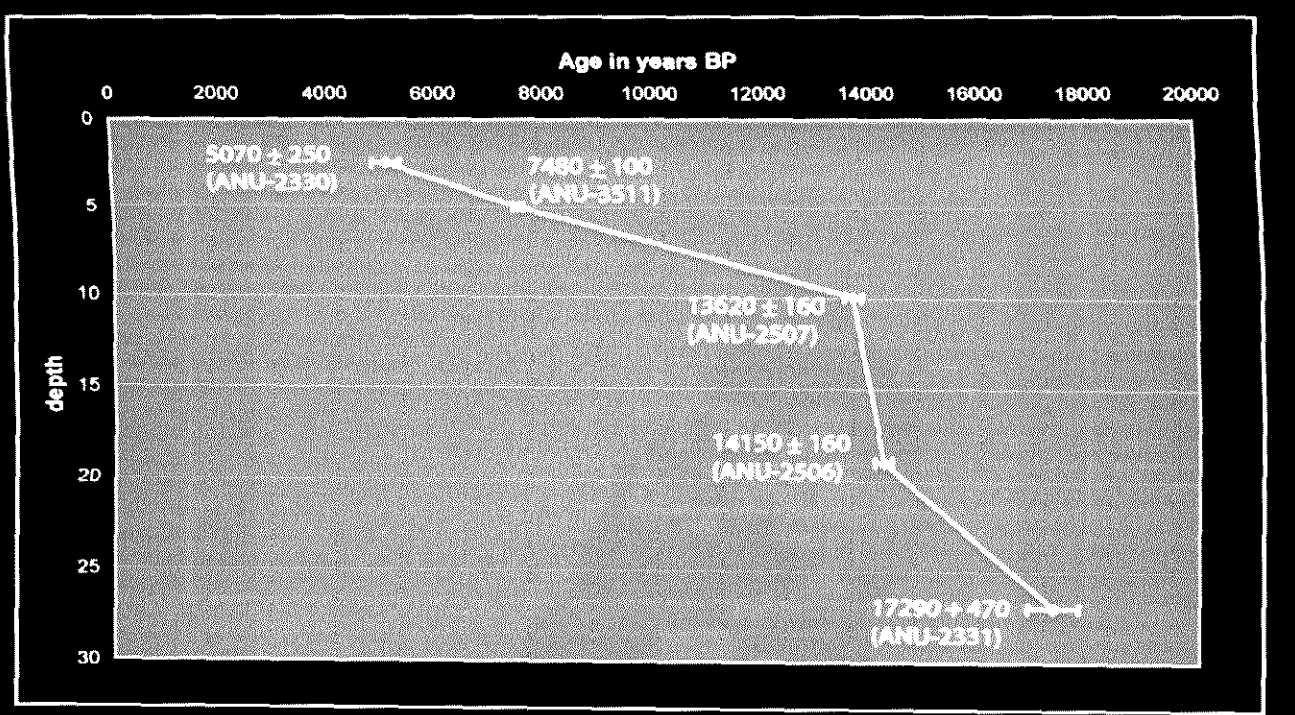

Figure 3.8: Age-depth curve for square P46 at Colless Creek Cave, Lawn Hill, northwest Queensland. The basal date of 17,290 ± 470 years BP (ANU-2331) (20,740 ± 660 cal BP) marks the bottom of the Unit A sediments.

On the basis of the age - depth curve, Hiscock was able to construct a geomorphic history for Colless Creek Cave consisting of five stages (Table 3.). The break in deposition between units A and B occurs at approximately 18,000 BP (21,000 cal BP), during the height of the LGM. As no dates were obtained lower in the sequence, it is not possible to gauge the rate of sediment accumulation. However it is likely that the accumulation and erosion of unit B and the lag that caps it must be in the realm of thousands of years.

phase	time period	geomorphic history
5	4 000 - 0 BP	accumulation of mid-Holocene sediments no perceivable hiatus (thin at rear of cave, thicker at front) sedimentation rates decline during last 3000 years - distinguished by presence of backed artefacts, increased charcoal, fresher shell
4	8 000 - 4 000 BP	erosion of earlier unit A sediments (very little at rear of cave, almost total at front)
3	18 000 - 8 000 BP	accumulation of unit A sediments during terminal Pleistocene
2	Prior to 18 000 BP	erosion of upper portion of Unit B removal of finer sediments from cave Formation of lags of gravel and artefacts in erosion channels
1	prior to 18 000 BP	accumulation and weathering of Unit B sediment

Table 3.2: Geomorphic history of Colless Creek deposit Lawn Hill, northwest Queensland (after Hiscock 1988:171).

The rate of sediment accumulation within the P46 square from the lowest dated spit (spit 10) until the surface is shown in Table 3., where sediment accumulation is generally within around 1 kg of sediment per 100 years. Between the dates of 14,150 BP (17,480 ± 140 cal BP) (in spit 8) and 13,620 BP (17,040 cal BP) (in spit 6) sediment accumulation increases to almost nine times the rate of other periods.

Spit	Years BP	Time Span	Sediment Deposition kg/m²/100yrs
P46/1	0 - 2450	2450	0.250
P46/2	2450 – 7300	4850	0.260
P46/3	7300 – 8750	1450	0.750
P46/4	8750 - 11850	3100	0.380
P46/5	11850 - 13625	1775	0.600
P46/6-7	13625 - 13800	175	8.800
P46/8	13800 - 14700	900	2.340
P46/9	14700 - 16400	1700	1.380
P46/10	16400 - 17600	1200	1.750

Table 3.3: Sedimentation rate for square P46 at Colless Creek Cave, Lawn Hill, northwest Queensland (after Hiscock 1988:606)

Change in stone artefacts in square P46

Hiscock's excavation examined changes in stone artefact discard and manufacturing processes through time. The P46 test pit produced 3,020 artefacts (2,341 from Unit A and 679 from the lower undated Unit B). Vertical changes in artefact frequency was measured in two ways: *(i)* number of artefacts per kilogram of sediment; and *(ii)* the number of artefacts per cubic metre. In P46 the frequency of stone artefacts was found to be very high in the upper layers, declining until spit 10 possibly due to an erosional feature. Below the lag in Unit B artefact frequencies were extremely low. Plots of artefact size by weight reveals a similar trend. On the basis of this analysis Hiscock developed a three phase occupation sequence for the site.

Spit	Unit	Volume	number of artefacts	number / kg	number / m³	total weight (g)	average weight (g)
1	A	0.004	217	35.6	54 250	418	1.9
2	A	0.008	451	35.8	56 375	452	1
3	A	0.005	247	22.7	49 400	356	1.4
4	A	0.006	243	20.8	40 500	348	1.4
5	A	0.006	101	9.5	16 833	178	1.8
6–7	A	0.012	128	8.3	10 667	588	4.6
8	A	0.010	231	11.0	23 100	1665	7.2
9	A	0.009	170	7.3	18 889	1118	6.6
10	A	0.007	553	26.3	79 000	1201	2.2
11	B	0.007	274	20.9	39 143	427	1.6
12	B	0.005	64	5.6	12 800	62	1
13	B	0.008	72	6.9	9 000	50	0.7
14	B	0.009	74	5.6	8 222	65	0.1
15	B	0.006	40	3.9	6 667	53	1.3
16	B	0.005	31	3.3	6 200	30	1
17	B	0.006	22	2.2	3 667	16	0.7
18	B	0.005	22	2.2	4 400	11	0.5
19	B	0.006	16	1.8	2 667	8	0.5
20	B	0.006	15	1.3	2 500	6	0.4
21	B	0.008	15	1.3	1 875	11	0.7
22	B	0.007	21	1.6	3 000	10	0.5
23	B	0.006	13	1.1	2 167	4	0.3

Table 3.4: Artefact frequency by sediment weight, volume and average weight of stone artefacts for all 23 excavation units for square P46 at Colless Creek Cave, Lawn Hill, northwest Queensland.

The first phase of occupation which occurs before 16,400 BP, is represented by the Unit B artefacts. Phase 1 is characterised by small chert flakes with an average weight of 1.6 g. The assemblage for this period was not consistent with the 'Core Tool and Scraper' tradition described for Late Pleistocene Australia (Bowler *et al* 1970). Hiscock argued that the phase 1 artefacts at Colless Creek were probably older than most 'type' sites known at the time, and stone artefact manufacture at Lawn Hill might be different to those sites. However, it was difficult to address this issue as few archaeological reports made mention of flake characteristics with which to compare the Colless Creek data (Hiscock 1988:175).

During phase 2 (16,400 BP to 13,500 BP) the average weight of artefacts was much higher than in phase 1. Mean artefact weights for each spit exceeded 4 g. In phase 3 (13,500 BP to the present) the average weight of artefacts was 1.4 g, and remained constant over this 13,500 year period. No evidence of a 'small tool tradition' was noted. On the basis of this analysis changes in the abundance of stone artefacts did not represent an observable trend (Figure 3.9).

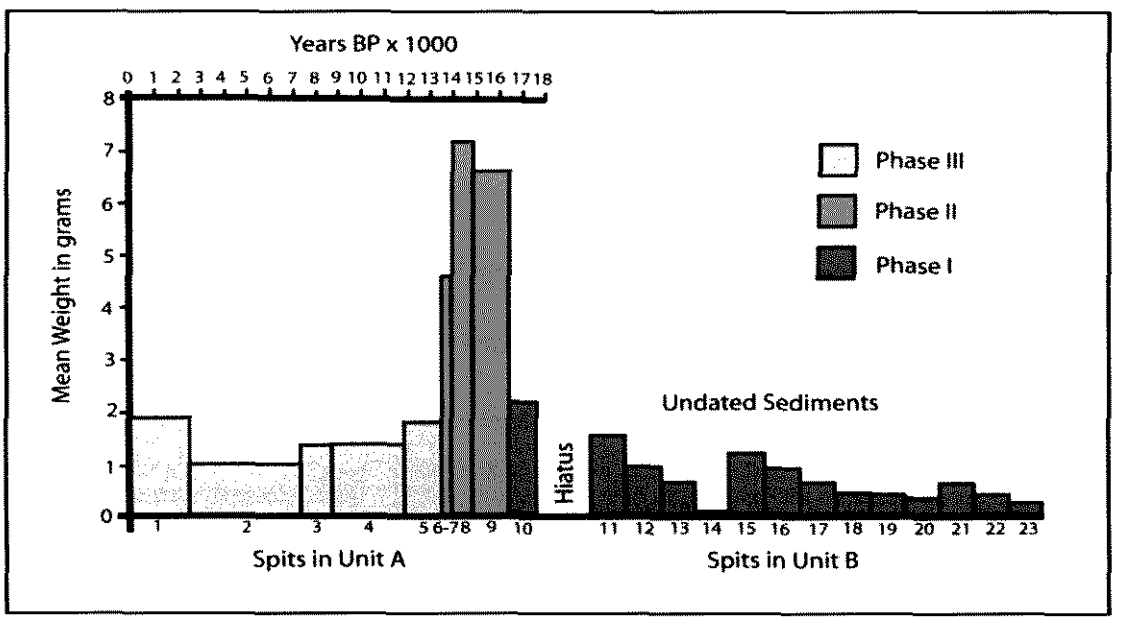

Figure 3.9: Average weight of artefacts for each spit in square P46 at Colless Creek Cave, Lawn Hill, northwest Queensland (from Hiscock 1988:611).

The different classes of stone artefacts from P46 (cores, flakes, retouched flakes, and flaked pieces) were also compared. In Unit A, cores and retouched flakes were only present in very low percentages. Cores were absent in Unit B with retouched flakes found in very small quantities. Cores and retouched flakes were most common in spits 6 - 10 (13,600 BP - 17,640 BP). Comparison of retouched flakes with unmodified flakes showed that the retouched flakes were twice the weight of unmodified flakes between 13,000 BP to 16,000 BP, and were much larger at other times. This is considered to be the result of greatly varying sizes of unretouched flakes and constant sizes in retouched flakes in the assemblage.

Hiscock considered that the changes in artefact discard at Colless Creek Cave may have been due to a variety of mechanisms: methodological error, post-depositional modification, spatial differences in the location of discard areas within the cave, changes in the system of artefact manufacture and use, varying intensity of site use, environmental stress, and population increase in the region.

Methodological error and post-depositional modification

Methodological factors that might affect the interpretation of the P46 results include post-depositional changes in the radiocarbon activity of the mussel shells used for radiocarbon dating, breakage, and downward movement of artefacts through the deposit due to trampling (see Hiscock 1988:179-180). Changes in radiocarbon activity are unlikely as x-ray diffraction results for samples of shell showed no evidence of any re-crystallization of carbonates (Hiscock 1988:187). Age determinations obtained from squares beyond P46 also showed good stratigraphic correlation with the P46 samples.

Spit	Number of artefacts	Percentage of Artefact Types in each Spit of P46			
		Flakes	Cores	Retouched Flakes	Flaked Pieces
1	217	90	0.5	2	8
2	451	92	0	2	6
3	247	91	0.5	2	7
4	243	95	0.5	0	5
5	101	92	0	1	7
6-7	128	88	2	1	9
8	231	73	5	1	20
9	170	77	2	3	18
10	553	87	1	2	10
11	274	92	0	2	6
12	64	88	0	0	13
13	72	97	0	0	3
14	74	93	0	0	7
15	40	78	0	5	18
16	31	90	0	0	10
17	22	77	0	0	23
18	22	96	0	0	5
19	16	81	0	0	19
20	15	93	0	0	7
21	15	87	0	0	13
22	21	81	0	0	19
23	13	85	0	0	15

Table 3.5: Frequency of artefact types in each spit of P46 at Colless Creek Cave, Lawn Hill, northwest Queensland (Hiscock 1988:619)

Breakage of artefacts results in a greater abundance of small artefact fragments. If breakage acted as the mechanism creating the flaked stone assemblage an inverse relationship between artefact size and artefact number would be expected. In P46 this process cannot explain stone frequencies, particularly between spits 6 and 10 where both the largest pieces and the greatest density of material are found.

Finally, if vertical downward movement of artefacts had occurred in the P46 square due to a mechanism such as trampling, smaller more angular and thin artefacts should be moved further downwards than larger material. However, the reverse is true in P46, and there is no observable pattern of gradual change in the size of artefacts with depth (Hiscock 1988:189). Further testing of the 'post-depositional hypothesis' included conjoin analysis and examination of decay related changes in lithic material (smoothing and rounding of margins, luster of surfaces). All conjoins in P46 came from the same spits (Hiscock 1988:190), and the extent of weathering was not consistent with vertical displacement of material. Stone was categorized based on appearance as one of four classes of weathering: fresh, lightly patinated, patinated, or heavily weathered (see Hiscock 1988:191), and showed that there had been only limited displacement of material. The presence of a few patinated artefacts in more recent spits may be related to the re-use of old flakes rather than disturbance.

Spatial variation

Removal of large artefacts from the front to the rear of the cave during the period 13,500 BP – 17,600 BP could explain the frequency of larger flaked stone in square P46. Excavations to the squares S37, K39, T39, and U39 were conducted in order to determine if similar sequences to the P46 record were present. The excavations revealed that the front area of Colless Creek Cave had been extensively scoured and the antiquity of the deposit here was only considered to be in the range of 4,000 to 8,000 years (Hiscock

1988:199). The assemblage from T39 allowed for a comparison of artefact size with material from P46. Only one radiocarbon determination was obtained for T39, a basal date of 16,170 ± 260 BP (ANU-2508) from spit 6, approximately half way down the deposit. The separation of phases 3 and 2 was determined on the basis of the presence of backed artefacts in spit 2, which were argued to be mid-Holocene in age (Hiscock 1988:199). Given recent Pleistocene antiquities for these artefacts in this region (Slack *et al.* 2004), the separation of the T39 square phases may be less certain today. The gross trends observable in terms of size and abundance of material in P46 were mirrored in T39 indicating that discard patterns were relatively constant throughout the occupation of the site. The analysis of micro-debitage in P46 showed that discard was analogous to the macroscopic assemblage and that a greater amount of knapping occurred in phase 2 than phase 3 (Hiscock 1988:205).

Technological changes

Hiscock argued that the increase in artefactual discard at Colless Creek Cave in phase 2 was most likely due to technological change through two possible mechanisms: *(i)* the removal of more flakes from cores than during phase 3, and *(ii)* a greater amount of cores were transported into the site and were reduced at the same level of intensity as during phase 3 (Hiscock 1988:241). In order to ascertain which (or both) of these mechanisms was operating, Hiscock completed detailed attribute analysis of chert flakes from P46. A total of 1,163 artefacts were selected and separated into an upper sample (phase 3: spits 1 and 5), middle sample (phase 2: spits 6, 7, 8 and 9), lag sample (spit 11), and a lower sample (phase 1: spits 12 – 23). The P46 analysis examined breakage patterns, heat treatment, knapping techniques, raw material selection, the nature of reduction, and the length of reduction.

(a) Breakage patterns

Highest levels of breakage were found in phase 3 and the lowest in phase 1. Distal fragments occurred more often than proximal fragments, and longitudinally broken flakes were more common as proximal fragments than distal. Almost twice as many longitudinally cone split flakes occurred in phase 2 than in phase 3, correlating well with other data indicating less knapping at the rear of the site after during phase 3.

	phase I		**phase II**	**phase III**
	lower	**lag**	**middle**	**upper**
Percentage of flakes broken	34.9	27.3	35.7	42.0
percentage of proximal fragments	10.5	4.7	9.2	9.9
percentage of medial fragments	1.4	2.7	2.1	6.8
percentage of distal fragments	12.7	8.2	14.7	16.7
percentage of longitudinally cone split fragments	8.6	9.0	6.7	4.8
percentage of fragments with both transverse and longitudinal breaks	1.7	2.7	2.9	3.4
Ratio of transverse to longitudinal breakage	2.9:1	1.7:1	3.9:1	7.0:1

Table 3.6: Breakage of flakes in Square P46, Colless Creek Cave, Lawn Hill, northwest Queensland (after Hiscock 1988:639)

(b) Heating

Although many artefacts showed evidence of heat treatment, only three flakes in the uppermost spits of P46 showed evidence of controlled heat treatment. Almost all heated treated artefacts were subjected to uncontrolled and excessive heat after flaking took place (Hiscock 1988:208). It is most likely that heat alteration occurred as a result of fires lit on top of already discarded flakes.

(c) Knapping Techniques

All flakes were produced using direct percussion, with no evidence of pressure flaking or indirect percussion. Bipolar flaking only occurred in retouched flakes in spits 2 and 3, totaling 5. As such, changes in knapping technique do not account for the changes in artefactual material in the site.

(d) Raw Materials

Most of the analysed artefacts were locally obtained chert. R-chert was found to be more common throughout the deposit than Q-chert, with a much higher proportion of R-chert to Q-chert in the middle and lag sequences.

level	percentage chert	percentage local stone non-chert	percentage non-local non-chert
upper (n=293)	97.93	1.38	0.69
middle (n=252)	98.41	1.59	0.00
lag (n=257)	99.22	0.00	0.78
lower (n=361)	98.62	0.28	1.10

Table 3.7: Changes in the frequency of raw materials in P46, Colless Creek Cave, Lawn Hill, northwest Queensland (from Hiscock 1988:660)

(e) Reduction

Detailed analysis of reduction processes examined the force and location of blows, the nature of core maintenance, and decortication procedures. Removal of cortex constitutes the first procedure during reduction, as knappers prepare the core. Hiscock found that the number of decortication flakes peaked strongly during phase II indicating the removal of more cortex than during other phases. This may be related to the reduction of larger cobbles, from variations in cobble shape, decortication procedures and/or the amount of post-decortication reduction. During early periods (phase 1) removal of cortex commonly involved the removal of complete flakes on predominantly retouched flakes. In the later period (phase 3), cores were increasingly the source of decortication flakes. During phase

2, decortication flakes that could be traced to more than one core platform became prevalent. However, the incidence of stone artefacts in P46 is highest for flakes with no dorsal cortex, indicating other technological strategies.

Amount of Cortex	phase I		phase II	phase III
	lower	lag	middle	upper
% indeterminate	0	1.6	4	1.3
% flakes with 0 cortex	78.5	82	65.1	73.6
% flakes with < 25%	9.5	8.2	9.4	12
% flakes with 26-50%	8.6	4.4	12.1	5
% flakes with 51-75%	3	0	3.4	3.1
% flakes with 76-99%	0.4	1.1	4	1.9
% flakes with 100%	0	2.7	2	3.1
number of flakes	232	183	149	159

Table 3.8: Changes in the amount of cortex on flakes from square P46, Colless Creek Cave, Lawn Hill, northwest Queensland (Hiscock 1988:642)

(f) Applied force

Attributes including platform size, prevalence of shattering, area of ventral surfaces, and termination types indicate the nature and intensity of applied force. At Colless Creek Cave differences in the area of ventral surfaces of flakes indicate that average force of blows was least in phase 1 and greatest in phase 2. This is supported by the greater occurrence of outré passé terminations during phase 2. The greatest frequency of platform shattering occurs during phase 2. Analysis of termination types examined the extent of control – feather and axial terminations indicating good control, whilst outré passé, step, and hinge terminations represent errors and lack of control by the knapper. Feather terminations were found to be highest during phase 2 and lowest during phase 3, indicating that forceful knapping in phase 2 was relatively successful in controlling fracture. In phase 3 decreases in applied force were accompanied with slight decreases in control as shown in Table 3.

(Hiscock 1988:213).

Termination type	phase I		phase II	phase III
	lower	lag	middle	upper
% feather	80.2	79.8	82.6	77.9
% hinge	12.1	16.9	12.1	17.7
% step	7.8	3.3	4.7	3.8
% outré passé	0	0	0.7	0.6
number	232	183	149	158

Table 3.9: Changes in the termination types on flakes from square P46, Colless Creek Cave, Lawn Hill, northwest Queensland (Hiscock 1988:647).

(g) Location of force application

The location of blows on cores will greatly affect the size and shape of resulting flakes. Four components were examined by Hiscock: *(i)* the nature of the platform surface on which the blow is located, *(ii)* the proximity of the blow to the core edge, *(iii)* its placement relative to ridges on the core face, and *(iv)* selection of appropriate platform angles (Hiscock 1988:213). This analysis highlighted subtle changes in the P46 deposit.

Platforms were found to have never been prepared by faceting or grinding, but were most often prepared by removal of one or two flakes. The amount of unprepared cortical platforms was found to increase steadily through the sequence, as did the use of weathered cracks as platform surfaces (Table 3.). These trends are consistent with a focus on knapping retouched flakes in phase 1, which later changed a focus on removal of flakes from cores during phases 2 and 3 (Hiscock 1988:214).

Platform surfaces	phase I		phase II	phase III
	lower	lag	middle	upper
% indeterminate	10.3	3.8	3.4	10.1
% cortical	5.2	6.0	8.1	10.8
% incipient plane	0.9	1.6	4.7	3.8
% shattered	2.2	3.8	2.7	4.4
% single scar	72.8	76.0	72.5	62.0
% several large scars	8.6	8.7	8.7	8.9
% faceting	0.0	0.0	0.0	0.0
% ground	0.0	0.0	0.0	0.0
number	**232**	**183**	**149**	**159**

Table 3.10: Changes in platform types on flakes from square P4, Colless Creek Cave, Lawn Hill, northwest Queensland (Hiscock 1988:648).

The location of blows in relation to the core edge changed significantly through the sequence of occupation. In the earlier phase 1, blows were applied only a small distance from the core edge. During the lag and middle sample (phase 2) the location was significantly further into the core platform. Focal platforms (a result of locating the hammer close to the core edge) were least common in phase 2 and most common in phase 3, indicating that blow application was more precise during phase 2. Further corroboration is supplied by analysis of overhang removal from the core face which was shown to be more prevalent in the upper and lower phases. In simple terms this analysis shows that through time there was an increase and then a decrease in the distance from the platform edge struck by knappers. The increased flake size shown during phase 2 can therefore be directly attributed to this behaviour (Hiscock 1988:214).

Placement of blows relative to dorsal ridges showed differences through the P46 assemblage. During phase 3 flakes have far less pronounced dorsal ridges and are more irregular in cross section. Hiscock argued that this shows a tendency for the selection of

more gently curving cores and removal of many small flakes rather than a few large ones. In phases 2 and 3, flakes have steeper platform angles than the early phase 1 flakes. This feature is correlated to the preference for knapping cores rather than retouched flakes which in turn led to larger flakes in phases 2 and 3 (Hiscock 1988:214-15).

Summary of chronological changes in artefact size

The changes in the force and location of blows and the patterns of decortication along with core morphologies are primarily responsible for the chronological changes in artefact size in square P46 at Colless Creek Cave. During phase 1 small flakes were the result of knapping retouched flakes. Within the lag and phases 2 and 3 of the deposit larger artefact size occurred primarily due to a change in the nature of reduction as removal of flakes from cores prevailed. The variation in the size of flakes within the middle and upper phases are also related to differences in the location, and intensity of applied force.

The raw material characteristics of R-chert and Q-chert nodules required different decortication procedures and core maintenance. Q-chert with a thicker, softer cortical surface required the preparation of platforms, whilst R-chert with thinner, hard cortex did not. During phase 2 most cores are R-chert and decortication was often completed by creating several platforms. Forceful blows applied further from the edge of cores proved a good means of creating large flakes and creating platforms. It follows that changes in artefact size in phases 2 and 3 of the deposit reflect the number of flakes created after decortication. During phase 3 more post-decortication flakes were removed than in previous phases, thereby creating greater quantities and generally smaller debitage.

Length of Reduction

In order to test the above changes in the number of flakes struck from cores, Hiscock examined the length of reduction by the number of flakes with marginal or distal scars on

their dorsal surface surfaces measured against the number of platform removal flakes (supposing that only one platform removal flake was produced in each rotation of a core). The number of flakes of this type thereby indicated the number of flakes struck off between rotations (Hiscock 1988:217).

During the Holocene (phase 3) 20-30 flakes constituted the maximum number of flakes removed from chert cores (Hiscock 1988:216). Phase 2 (terminal Pleistocene and pre-LGM) reduction was of relatively short length and characterised increased transportation of cores to the site but with fewer flakes being removed (Hiscock 1988:217).

Changes in artefact manufacture between phases 2 and 3 are also related to raw material procurement. Phase 3 with light precise knapping, removal of greater numbers of small thin flakes, smaller more regularly shaped cores, features much greater reduction of Q-chert than during phase 2 [Hiscock estimates 24-40% of all stone during phase 3 was acquired at more distant sources (Hiscock 1988:218)]. During the earlier phase 2, knapping featured more forceful imprecise blows, little overhang removal and less reduction of cores (Hiscock 1988:218) reflecting less concern with conserving cores (Hiscock 1988:219). During phase 2 there was far less exploitation of the stone resources of the plateau than during phase 3, and was concentrated mainly on locally obtained R-chert from river cobbles from Colless Creek.

Changes in site use, environmental stress, and population increases

Simple functional measures of the use of Colless Creek Cave combined with the technological analysis described above document changes in the intensity of occupation occurring over the last 17,000 years. Four measures of the extent of site usage were examined by Hiscock including: *(i)* the use of fire, *(ii)* the intensity of trampling, *(iii)* the frequency of artefact use and *(iv)* the amount of food consumed. All of these measures were found to correlate well with the sequence established for technological changes in

stone artefact manufacture, indicating greater intensity of occupation between 13,500 BP and 17,600 BP.

Three interrelated hypotheses have been offered to explain the changes in occupation intensity: *(i)* an increase in cave use, *(ii)* environmental stress forcing people to focus on the immediate area around the site, and *(iii)* an increase in regional population (Hiscock 1988:220). If the occupation intensity is related to a change in preference for cave sites then the archaeological material should indicate a similar pattern of resource use through time. Alternatively if the intensity is due to climatic stress as the result of aridity, Hiscock argued that archaeological material should reflect a change in the pattern of resource use through time (Hiscock 1988:220).

Use of fire

Hiscock examined the intensity of the use of fire in Colless Creek Cave as an independent measure of site usage. This was done by examination of the numbers of pot-lids created by intense heat within the assemblage (Hiscock 1988:221). This analysis found that the number of chert pot-lids showed a close correlation through time with the trend for artefacts, and was also related to changes in the rates of sedimentation. The period between 13,500 BP and 17,000 BP is thought to feature the most intensive use of hearth fires.

Treadage

The rate of transverse breakage of artefacts through treadage should be inversely related to the rate of sedimentation. If breakage rates do not reflect this inverse relationship, then deviations are most likely the result of human treadage. Hiscock found that at Colless Creek cave treadage was most intense in spits 6/7 and 8, between 13,500 BP and 15,000 BP as shown in Figure 3.10 (Hiscock 1988:223).

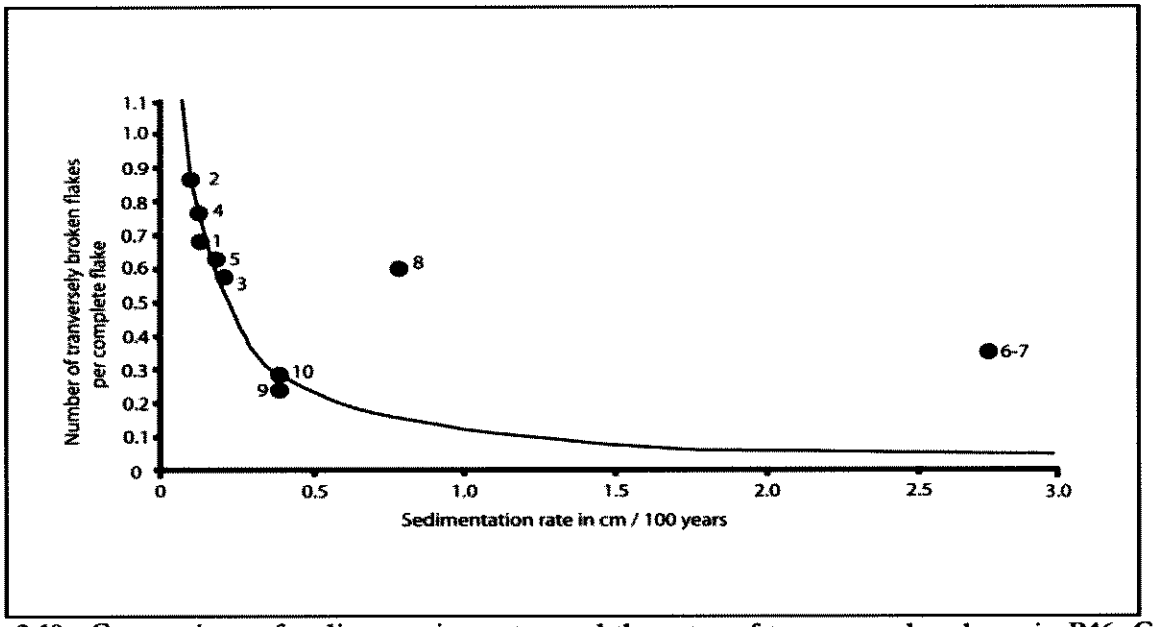

Figure 3.10: Comparison of sedimentation rates and the rates of transverse breakage in P46, Colless Creek Cave, Lawn Hill, northwest Queensland (after Hiscock 1988:657).

Changes in artefact use

There was greater edge damage on complete flakes than broken flakes throughout P46, indicating that such damage was the result of use rather than taphonomic factors. The prevalence of edge damaged artefacts during phase 2 mirrors the frequency of retouched artefacts (Hiscock 1988:224).

Examination of the number of retouched flakes within an assemblage will allow a rough measure of the intensity of stone use activities (Hiscock 1988:224). In P46 Hiscock found that the frequency of retouch increased from phase 1 to 2 and declined from phase 2 to 3, suggesting that phase 2 was a period of more intensive tool use (Hiscock 1988:224).

Changes in raw material procurement

The analysis of stone raw material focused on the division between local and non-local material, with local material (occurring within the gorges and less than 3 km from the site) including chert and limestone, whilst non-local raw materials (greater than 3 km) including greywacke, sandstones, quartzite's and silcrete. Most of the P46 assemblage consisted of local material. However, quartzite occurred in phase 3 (spits 1, 2, 3) and phase 1 (spits 11,

14, 15, and 22), quartz in spit 14, and one greywacke flake in spit 4 (Hiscock 1988:225). The infrequency of non-local material does not strongly relate to distance, as quartzite's and greywackes are found only 3 km to the north. No non-local material occurs in the middle sample (13,500 BP to 17,600 BP). Hiscock suggests that this indicates a reduction in territory exploited due to increased environmental stress during phase 2 occupation. However, it is equally possible that this represents a rescheduling of either stone procurement strategies or the use of the cave during this time.

Changes in faunal exploitation

Faunal remains were analysed by Aplin (n.d.) who concluded that they were largely deposited by anthropogenic actions, and a high degree of burning and fragmentation was noted. The rate of shell accumulation was very similar to the rate of artefact discard, with greater amounts accumulated during the terminal Pleistocene. Bone debris only increased significantly in spits 6 and 7, coinciding with an increase in fish remains, and a reduction in mammal and turtle (Hiscock 1988:226) (Table 3. and Table 3.).

spit	mammal	turtle	fish	snake	lizard	bird	sample
1	65.2	13.0	20.3	0.0	1.4	0.0	69
2	60.2	31.4	5.1	3.4	2.5	0.0	118
3	53.8	9.6	26.0	4.8	3.8	0.0	104
4	54.6	13.1	25.4	5.4	1.5	0.0	130
5	59.0	5.1	32.5	3.4	1.7	0.9	117
6	34.9	2.3	58.1	2.3	2.3	0.0	43
7	26.5	4.4	64.7	1.5	1.5	0.0	68
8	41.4	24.1	27.6	6.9	0.0	0.0	29
9	-	-	-	-	-	-	-
10	92.3	0.0	0.0	7.7	0.0	0.0	13

Table 3.11: Composition of Vertebrate faunal sequence from square P46, Colless Creek Cave, Lawn Hill, northwest Queensland. Percentage abundance has been calculated by number after Aplin n.d. (Hiscock 1988:664).

spit	bone (g/100yr)	shell (g/100yr)
1	1.58	4.04
2	1.32	3.25
3	4.44	8.60
4	1.86	2.95
5	2.42	8.36
6-7	36.13	330.23
8	1.79	100.81
9	3.45	59.19
10	5.62	8.75

Table 3.12: Estimated rates of bone and shell accumulation in P46, Colless Creek Cave, Lawn Hill, northwest Queensland. after Aplin n.d. (Hiscock 1988:663)

During phase 3 an overall reduction in discard of faunal remains occurs. Hiscock suggests that the change reflects a reduction in the amount of food prepared and consumed on site, and that the increase in shell and fish remains that occurs between spits 6 and 9 reflects a greater reliance on resources within the gorge. This is also a prevalence of locally available R-chert stone discarded during this period.

Summary

The Colless Creek data indicate an antiquity of occupation that predates the onset of the last inter-glacial. Assertions by Hiscock and others that occupation extends to 35 - 40 000 BP are hypothesized on the available data. It is uncertain how much time is represented by the lag deposit between units A and B. It is also uncertain whether occupation at Colless Creek extended to the LGM and OIS2, and whether the lag phase represents a hiatus in occupation. If this feature does represent a hiatus then the previously held model of Lawn Hill as a refuge is uncertain.

The most dramatic change in the Colless Creek Cave sequence occurs directly after the Last Glacial Maximum in the lowest dated units of the site. The period between 13,000 BP and 17,000 BP shows the most intensive occupation of the site and a apparent reduction in logistical and residential mobility. Both stone and food resources show a focus on the gorge area instead of the plateau. A reconfiguration of foraging activities at Colless Creek is also suggested by stone artefact reduction strategies. Responses to increased resource patchiness and uncertainty in foraging were manifested in greater control and precision in the reduction of this local stone raw material.

Hiscock's analysis clearly shows a reconfiguration occurred in subsistence strategies and settlement after the amelioration of the LGM (c 13,000 BP). The reappearance of non-local stone raw materials correlates to an expanded foraging range, and formal implements including backed artefacts and tulas proliferated at this time. At some time after 10,000 BP use of Colless Creek Cave declined. What is not clear from the Colless Creek data, is the extent of these changes in foraging, and so to address this issue Hiscock examined a second rockshelter known as Louie Creek Cave.

3.5.2 Louie Creek Cave

Background

Louie Creek Cave is a large limestone rockshelter with a northwest aspect located approximately 2 km south of Colless Creek Cave at the commencement of the dolomite Thorntonia limestone cliffs, and 400 m within an extensive gorge system along Louie Creek (Figure 3.11). The site was excavated by Hiscock to provide comparative data for the excavations at Colless Creek (Hiscock 1988). Louie Creek Cave, with its large suite of rock art was also recorded by Walsh as a part of his study of Lawn Hill (Walsh 1985).

Figure 3.11: The entrance of Louie Creek Cave at Louie Creek, Lawn Hill, northwest Queensland.

Location and environment

The cave is located on the southern side of the 50 m deep Louie Creek gorge, is approximately 15 m above the creek at base of scree slope and below a 20 m high cliff. At this location the creek flows southeast to northeast and a second smaller creek joins just east of the cave. Louie Creek is similar to that of Colless Creek, a shallow slow flowing course with numerous but small tufa dams. Hiscock (1988) suggested that the flow of Louie Creek may have been substantially greater in the past. It is known that the activities of European settlers have altered flow significantly in the last 200 years. Water flow in Louie Creek is permanent in most years and is partly fed by springs occurring in the middle of the watercourse. Several permanent pools of water near the cave contain fish, turtle, shellfish and edible plants. The banks of the creek are lined with water lilies (*Nymphaea violacea*), *Pandanus aquaticus*, *Melaleuca sp.* and *Ficus sp.* This local ecosystem supports a large range of animals and plant resources. R-chert is readily available in extensive gravel beds along Louie Creek.

Above the cave, the plateau has no water and is chiefly comprised of skeletal soils

vegetated by low eucalypt woodland, and groundcover of *Spinifex triodia*. Hiscock suggests that the main use of the plateau by foragers was probably for hunting but that some plant species may have been utilised for wood and resin for hafting implements. There are no known outcrops of knappable chert on the plateau. Immediately to the east of the site, Constance sandstone outcrops as a steep hill. *Eucalyptus Dichomopholia* dominates the vegetation, with a groundcover of *Triodia* spinifex. Along the base of the Constance outcrop, slabs of sandstone suitable for grindstones are readily available.

The Louie Creek Gorge is lined with rockshelters and open sites. Open sites are predominantly deflated shell middens and/or artefact scatters. The location of these sites is determined in part by proximity of the creek. Beyond the source (Garden Spring), approximately 2 km from Louie Creek Cave, archaeological site density is reduced. Along the limestone gorge, rockshelters, caves and fissures occur. At least five of these sites show indications of Aboriginal occupation in the form of art, surface scatters of stone artefacts and shell. In addition to the caves there are small, mostly horizontal tunnels of less than 1 m in diameter that extend into the limestone in places. At one location about 500 m from Louie Creek Cave a tunnel on an exposed surface has been decorated with a large red ochre band (25 cm in diameter) over which thinner white lines have been painted.

Site Setting

Louie Creek Cave is comprised of both the sandstone and limestone geological units. It has been formed by weathering of Precambrian sandstone which is overlain by Cambrian dolomite. The cave extends over 34 m into the cliff face and the entrance is 40 m wide and 3 - 5 m high. The total estimated floor area is 1,400 m^2 and much of this is covered in 2 - 4 cm of silt, except where water flow has exposed underlying sandstone bedrock (Figure 3.12). Large boulders at the entrance of the site have acted as sediment traps.

Figure 3.12: Plan of excavations at Louie Creek Cave, Lawn Hill, northwest Queensland (after Hiscock 1988:666-7). Excavated 50 cm x 50 cm squares are shown in yellow and the analysed square BJ29 is shown in red.

A low intensity scatter of flaked stone artefacts occurs on the floor of the cave and on the scree slope below. A large sandstone grindstone features in the northeastern entrance and a slab of roof fall further within the cave contains two ground pits. Extensive rock art occurs within and around the cave featuring freehand painting and drawings in a variety of colours. The largest of the motifs is a snake in white ochre that weaves its way around most of the entrance of the site. Other art includes hand stencils, baskets, and two spiral designs. The art contains examples of all of the proposed sequence for the region (Border 1988; Walsh 1985).

Excavations

In 1981 Hiscock excavated a series of test pits within Louie Creek Cave (Hiscock 1988). A total of six 50 cm x 50 cm squares were excavated (BL26, BL27, BL30, BL31, BJ29 and AS33). Five of these test pits were located in northwestern entrance area of the site where sediment was deepest, and a further square (AS33) was located 12 m to rear of the other

squares in order to provide a stratigraphic correlate (see Figure 3.13).

All of the test pits were excavated to bedrock, with the depth of the deposit varying from 35 cm - 60 cm in the main trench area in the northwestern entrance. In square AS33 the depth was *c.* 20 cm. These depths reflect the underlying slope and topography of the parent rock. Sediment was comprised of large gravel sized fragments of roof fall, and fine sediments derived from the plateau above that had been washed into the cave through fissures in the limestone rock. At the rear of the cave an extensive area also contained bat guano.

The stratigraphy of the test pits in Louie Creek Cave varies considerably and three squares contained what are described as hearths (BL31, BL30, BL26). One of the deepest squares at the front of the cave (BJ29) was selected for detailed analysis. Square BJ29 was excavated in thirteen spits of varying depth, and within BJ29 six different stratigraphic horizons were identified (Figure 3.13).

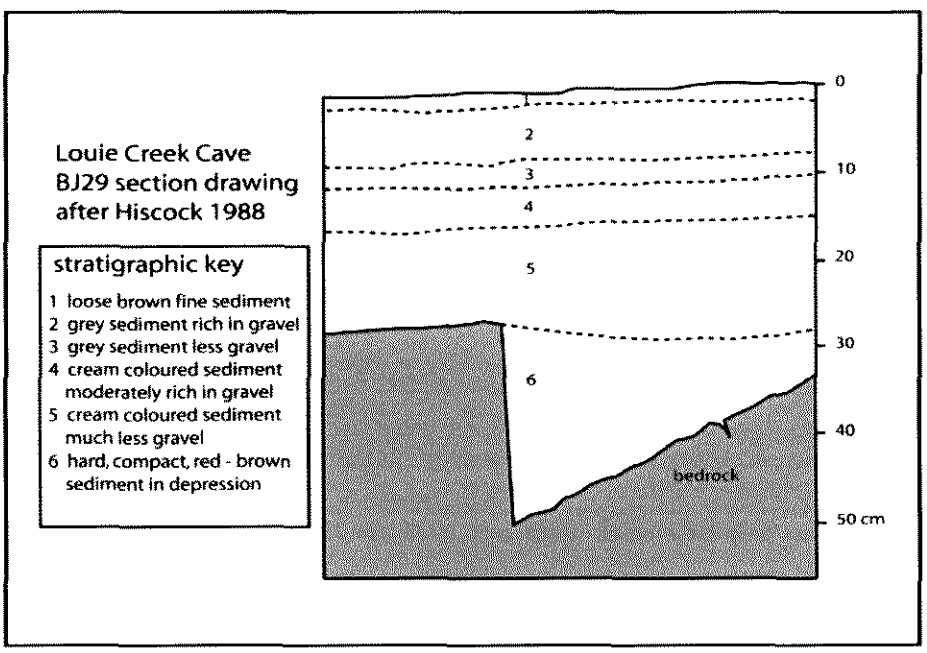

Figure 3.13: Section drawing of square BJ29 at Louie Creek Cave, Lawn Hill, northwest Queensland (after Hiscock 1988:233-34, 669).

Chronology

Three radiocarbon determinations were obtained on freshwater mussel shells from spits 5, 8 and 12 - 14. A bulk sample was submitted for the lower excavation levels of BJ29 due to low shell quantity. Spit 5 returned a date of 8,810 ± 130 BP, spit 8 was dated at 14,210 ± 230 BP (17,580 ± 220 cal BP) and the sample from spits 12 - 14 was dated at 18,600 ± 900 BP (19,820 ± 1,140 cal BP)(Hiscock 1988:670). An age - depth curve for square BJ29 is shown below in Figure 3.14.

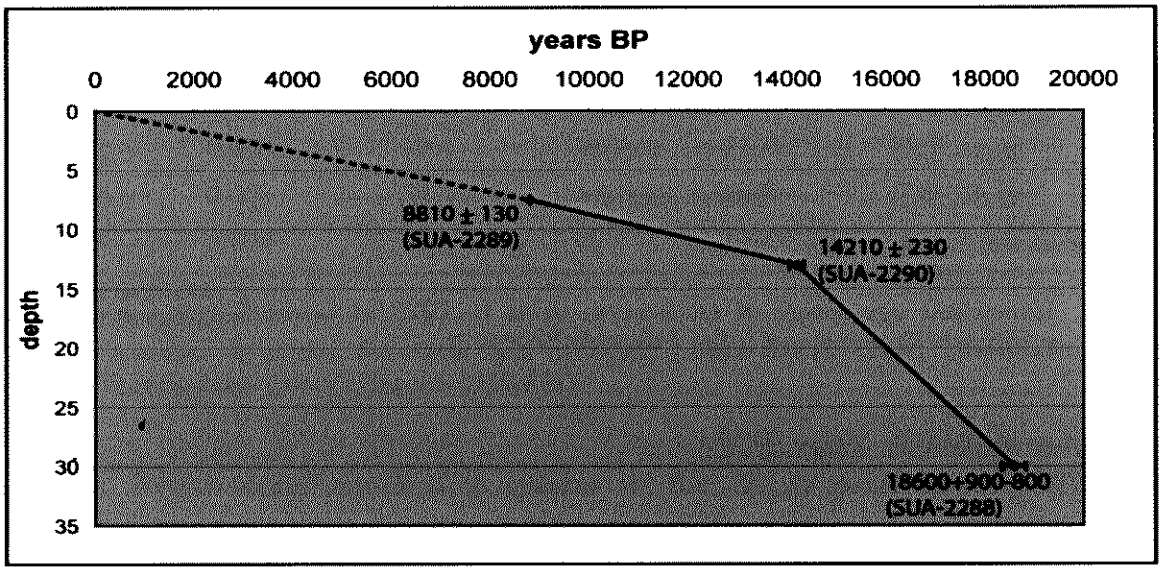

Figure 3.14: Age-depth curve for square BJ29 at Louie Creek Cave, Lawn Hill, northwest Queensland (after Hiscock 1988:670).

The radiocarbon determinations from BJ29 show increasing age with depth and sediment accumulation rates varying. In the upper levels there is a pronounced slower sediment accumulation rate relative to the lower units. In Layer 3 (Spit 6 at a depth of 8 - 9.75 cm) which represents the period between 8,000 and 10,000 BP Hiscock argues that deposition was probably much faster than the subsequent periods as there is an absence of roof fall. The lower spits, from 8 to 14 (from 14,000 BP) feature rapid sedimentation, which Hiscock argued, mirrors the sedimentation at Colless Creek Cave, and documents the effects of the Glacial Maximum aridity (i.e. increasing soil erosion on the plateau).

Spit	Approx. depth below surface (cm)	Years BP	Time Span (years)	Sediment Deposition kg/m²/100yrs
1	1.0	0 - 1100	1100	0.69
2	1.0 – 3.1	1100 - 4100	3000	0.26
3	3.1 – 7.0	4100 - 8350	4250	0.29
5	7.0 – 8.0	8350 - 9100	750	0.52
6	8.0 – 9.0	9100 - 10200	1100	0.13
7	9.0 – 12.0	10200 - 13100	2900	0.2
8	12.0 – 14.0	13100 - 14600	1500	0.51
9	14.0 – 18.0	14600 - 15500	900	0.97
10	18.0 – 22.0	15500 - 16650	1150	0.9
11	22.0 – 25.0	16650 - 17250	600	0.75
12	25.0 – 28.5	17250 - 18200	950	0.31
13	28.5 – 32.0	18200 - 19000*	800	0.75
14	32.0 – 35.0	19000 - 20100*	1100	0.06

* denotes hypothesis only

Table 3.13: Estimated age range of excavation units in BJ29 at Louie Creek Cave, Lawn Hill, northwest Queensland (after Hiscock 1988:672).

Change in stone artefacts in square BJ29

In BJ29 1,413 flaked stone artefacts over 2mm in size were recovered. Throughout most of the BJ29 sequence artefact discard rates are very low, varying between 3 and 7 artefacts per 100 years (Hiscock 1988:236). There are three periods when artefact discard is elevated; a moderate increase in discard in the last 1,100 years, moderate increase between 8,350 BP and 9,100 BP (spit 5) and significant increase between 14,600 BP and 17,250 BP in spits 9 - 11 (Hiscock 1988:236). Hiscock argued that these periods of increased discard represent times of greater intensity in artefact manufacture, and is also supported by similar trends in the amount of micro-debitage from this square. The variations in discard rates are said to reflect stone working intensity which was greatest at the front of the cave between 14,600 BP and 17,250 BP (Hiscock 1988:237) (Table 3.14).

Spit	layer	volume	number of artefacts	number / kg	number / m³	total weight (g) *	average weight (g) *
1	1	0.003	124	16.3	41333	78.1	0.72
2	2	0.007	131	16.8	18714	70.7	0.71
3	2	0.010	225	18.4	22500	88.8	0.46
5	2	0.002	79	20.3	39500	36.4	0.52
6	3	0.003	36	25.7	12000	5.8	0.21
7	4	0.007	89	15.3	12714	118.6	1.45
8	4	0.006	104	13.5	17333	79.5	0.81
9	5	0.009	151	17.4	16778	115.3	0.77
10	5	0.011	172	16.5	15636	57.5	0.34
11	5	0.007	111	24.7	15857	24.2	0.23
12	6	0.008	59	20.3	7375	22.7	0.39
13	6	0.008	52	8.6	6500	7.8	0.19
14	6	0.009	80	11.3	8889	2.7	0.04

* chert artefacts only
numbers from original

Table 3.14: Artefact densities for each spit of BJ29, Louie Creek Cave, Lawn Hill, northwest Queensland (after Hiscock 1988:673).

The size of flaked stone artefacts is greater in the upper parts of the BJ29 deposit. However, the change in artefact size at Louie Creek Cave does not simply relate to a change in raw material selection from Q-chert to R-chert as was the case at Colless Creek. No Q-chert material was identified in the deposit. Size comparisons show that between spits 7 – 9 (10,200 BP - 15,500 BP) artefacts were generally larger than at any other time in the rest of the sequence. Between spits 9 and 14 (14,600 BP - approx. 20,100 BP) flaked pieces were very uncommon, and retouched flakes and cores were completely absent. In fact discard prior to 14,600 BP was comprised of unmodified flakes. In addition to the R-chert, flakes made from limestone occurred infrequently in all spits of BJ29.

The most likely reason for the relationship between change in size of artefacts and the rate of discard from BJ29 is changing technology. After 14,600 BP a greater range of stone working activities were carried out within Louie Creek Cave, with the last 4,000 years

seeing a specific range of retouched artefact types including bifacial points, backed blades, and tulas occurring (Hiscock 1988:238).

Functional Changes

As with his analysis of the Colless Creek site, Hiscock examined four aspects of behaviour at Louie Creek to investigate simple functional change: (i) use of fire, (ii) treadage, (iii) raw material procurement, and (iv) faunal exploitation.

(a) Fire

Chronological changes in the use of fire were evident from heat shattered fragments of chert, and although the frequency of such pieces was small (an average of between 1 and 3 per 100 years) higher rates occurred in spits 1, 5 and 9 - 11 than in other spits. Hiscock concluded that this indicated brief increases in hearth fires over the last 1,100 years and between 8,350 and 9,100 BP, and that there was a period of "sustained increase" in hearth fires between 14,600 BP and 17,250 BP (Hiscock 1988:239). These periods of increased fire intensity track peaks in artefact discard rates.

(b) Treadage

All unretouched flakes larger than 6 mm from BJ29 were examined, and the ratio of transversely broken flakes to complete flakes was calculated as a measure of the intensity of occupation. Spits 13 and 14 showed very low rates of treadage. Conversely spits 9, 10, and 11 indicated much higher transverse breakage in relation to sedimentation rates. Hiscock argued that there was a much higher treadage during the period 14,600 BP and 17,250 BP than at any other time (Hiscock 1988:240) (Figure 3.15).

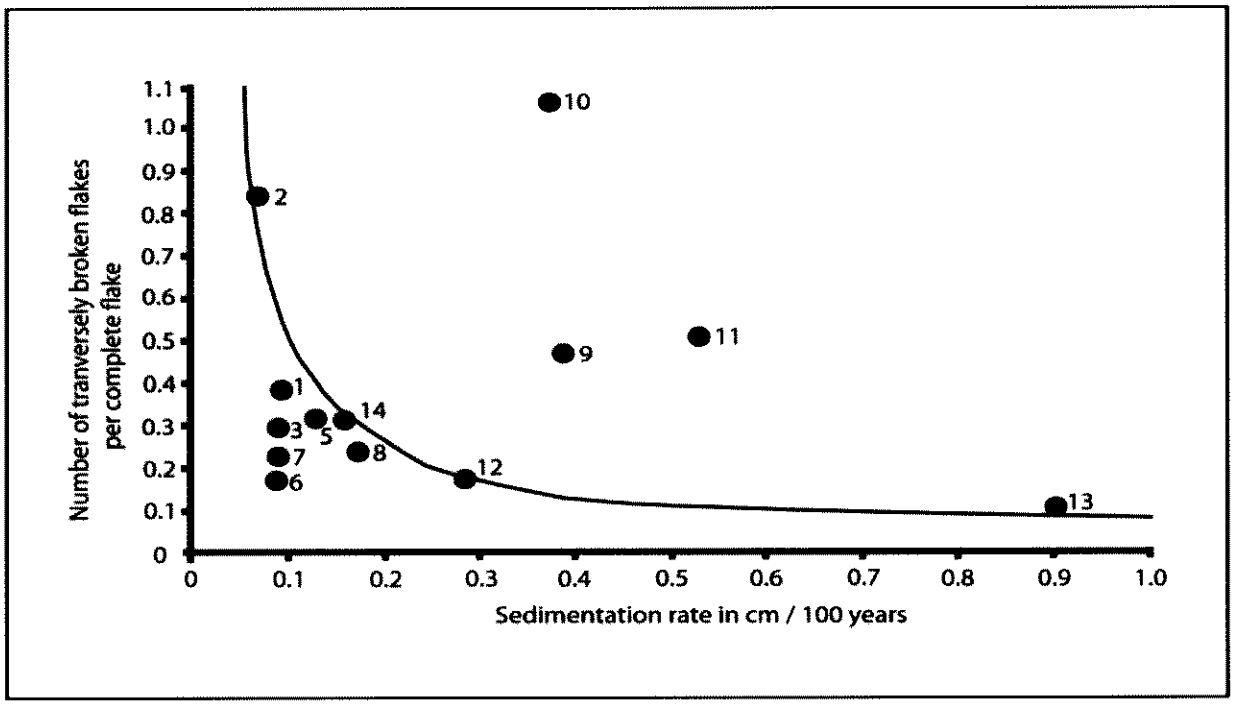

Figure 3.15: Comparison of sedimentation rates in BJ29 and the rates of transverse flake breakage Louie Creek Cave, Lawn Hill, northwest Queensland (after Hiscock 1988:683).

(c) Changes in raw material procurement

All local stone consisted of R-chert, limestone, and sandstone, whilst non-local material consisted of greywacke, quartzite, and silcrete. Within square BJ29 the great majority of stone artefact raw material is of local origin. Additionally, the discard of R-chert increases through time, peaking between 13,100 BP and 16,650 BP and subsequently decreasing up to the present (Hiscock 1988:241). Local limestone was used prior to 17,250 BP and after 9,100 BP, but between 17,250 and 9,100 BP R-chert was preferred. Flakes of non-local material were most commonly made on imported greywacke, and these account for a very small percentage of the assemblage (1.5 - 3% of the assemblage before 17,250 BP and after 14,600 BP respectively), and only occur in small numbers in just over half of the spits. No non-local material is found between 17,250 BP and 14,600 BP.

(d) Fauna

The faunal assemblage from Louie Creek Cave is small and largely unreported. Changes in the condition of faunal material exploited at Louie Creek Cave are largely explained as a result of anthropogenic factors. High levels of fragmentation are largely attributed to burning. Partially burnt and calcined bone increases with depth possibly due to the lack of preservation of unburnt bone in lower levels. Greater frequencies of bone relative to shell are evident in the lower units and parallel each other generally throughout the deposit. From 17,200 BP there is an increase in faunal material and then a steady decrease for the next 2,500 years (Table 3.15). These results suggest greater food preparation and consumption within the site during the period between 17,250 and 14,600 BP (Hiscock 1988:242). In fact, all the functional studies (artefact discard, burning, treadage, and faunal exploitation) indicated more intensive occupation during this time followed by a steady decrease a few thousand years later.

spit	bone (g)	shell (g)	Time (years)	Bone (g/100yr)	shell (g/100yr)
1	26.5	12.0	1100	2.4	1.1
2	46.8	21.1	3000	1.6	0.7
3	77.6	47.5	4250	1.8	1.1
5	28.4	12.6	750	3.8	1.7
6	7.4	3.2	1100	0.8	0.3
7	57.0	27.1	2900	2.0	0.9
8	51.6	19.6	1500	3.4	1.3
9	88.7	22.6	900	9.9	2.5
10	77.2	31.5	1150	6.7	2.7
11	31.0	11.7	600	5.2	2.0
12	26.3	8.6	950	2.8	0.9
13	25.2	4.8	800	3.2	0.6
14	17.0	7.9	1100	1.6	0.7

Table 3.15: Discard rates of bone and shell in BJ29, Louie Creek Cave, Lawn Hill, northwest Queensland (Hiscock 1988:687).

Summary

Although the excavations of Louie Creek Cave are not as detailed as those at Colless Creek Cave, it is clear that similar themes occur during the occupation of the site. The basal date of 18,600 BP is coincident with the extreme climatic conditions of the LGM, and the period immediately following this mirrors the changes to foraging that were observed at Colless Creek Cave.

Between 18,600 BP and 14,000 BP Louie Creek Cave appears to have been more intensively occupied than at any other time. Stone artefact discard is high, and there is increased use of fire and treadage. After 14,000 BP a greater variety of stone related tasks were completed on-site. It seems however, that occupation after 14,000 BP was much less intensive. Sedimentation rates are reduced for the period post 14,000 BP, and although stone discard is higher than for other periods, between 8,000 and 13,000 BP discard declines indicating a possible reconfiguration in settlement/subsistence activities. In addition, the discard rates of faunal material are meager for the entire deposit, prohibiting detailed modeling of the nature of foraging range and diet breadth at any time.

3.6 Chapter Summary

This chapter has summarized the results of Hiscock's previous research in the study area, detailing the analysis of flaked stone artefacts from Colless Creek and Louie Creek Caves. Hiscock's analysis revealed changes in the pattern and intensity of site use at these sites and suggests intensive use correlates with a contraction of range and territory during periods of climatic stress. This data provides for a model of fluctuating occupation of the Lawn Hill region.

Hiscock's Lawn Hill refuge model is based on observations concerning the use of local raw materials and emphasis on river resources during the LGM. This model relies heavily on *(i)* the presence and absence of greywacke at different times in the regional chronology; and

(ii) increased discard of mussel shell. However, it must be noted that greywacke is never a significant component of the assemblages at either site and that whilst shell discard is at its highest in a lens present in Spits 6, 7 and 8, this also occurs between 14,000 and 13,600 BP but at a rate of 100 - 300 g/100 years (Hiscock 1988:663; and see Cosgrove 1995:114). Table 3.2 shows that Spit 6 and 7, where most shell discard features occurs between 13,625 - 13,800 BP, a period of just 175 years. It is equally reasonable to suggest, that this accumulation might represent opportunistic harvesting of a tufa dam area during post LGM more productive river conditions.

The fluctuating settlement model developed from Lawn Hill suggests that this area (although small) was able to support a population of 20-30 people for a 4,000 year period (Hiscock 1988:260). However, the model does not adequately explain how a population was able to live in isolation in the gorge for such a long period of time, whilst still allowing necessary contact with other groups in order to reproduce successfully over many generations.

There is little evidence to support the assertion that Lawn Hill was either a 'refuge' or an occupied 'corridor' during the LGM (OIS2). At Colless Creek Cave, there is a hiatus in sedimentation and also probably occupation prior to 17,500 BP. At Louie Creek Cave the record of occupation dates to 18,000 BP, at the end of the LGM. Further data is needed for the period prior to 18,000 BP to determine whether Lawn Hill really represents an oasis for people retreating from the arid zone, or the first occupation of humans exploring an interior at the end of glacial conditions, using the permanent aquifer waterways to support this endeavor.

Chapter 4

Evolutionary Theory Part 1: Human Behavioural Ecology, Optimal Foraging Theory, and Stone Artefact Studies

4.1 Introduction

This chapter discusses the theoretical approach that has been applied to this research. It provides the background, and presents the concepts and models that are implemented to interpret the Riversleigh/Lawn Hill archaeological record. Anthropological and archaeological case studies, where similar approaches have been taken are discussed in relation to the present study.

This research utilises human behavioural ecology to develop a settlement model for the Lawn Hill/Riversleigh research area. There are a variety of reasons for using this approach including: *(i)* the application of evolutionary theory to an archaeological problem highlights the role that reproductive strategies and human decision making have on adaptation; *(ii)* the important premise that adaptive behaviour will often relate to changes in environment; and *(iii)* the models of human behaviour derived from this body of theory are testable against the archaeological record.

4.2 Human Behavioural Ecology

The first studies of Human Behavioural Ecology (HBE) emerged in the 1970s, borne from evolutionary ecological studies in the biological sciences (see Bird and O'Connell 2006; Charnov and Orians 1976; Dunnell 1980, 1996; Hutchinson 1965; Krebs and Davies 1978; Winterhalder and Smith 2000). Initially these studies focused on foraging theory with the aim of setting human oriented research within a wider cultural ecological approach

(Winterhalder and Smith 2000:51). The approach is particularly valuable to archaeological studies as it relates directly to food procurement and preparation.

The basic premise of HBE is that all behaviour tends towards optimization (see Foley 1985), and assumes that certain human groups, especially hunter-gatherers, are skilled and effective in their food quest (Bird and O'Connell 2006; Winterhalder 2002). Efficiency is important even if food is not scarce or hard to get, as it allows time and resources to be spent on other fitness enhancing activities (Smith 1978). HBE models provide one avenue for archaeological studies to investigate how food (and other material) procurement might fit within a particular culture.

Human behavioural ecologists commonly use four main theoretical approaches: *(i)* life history theory, *(ii)* sex allocation theory, *(iii)* the polygony threshold model, and *(iv)* optimal foraging theory. The first three approaches are essentially first order theoretical tenets and most often applied in studies of the very long term. *Life History* models posit that the physiological traits and behaviours of an organism are determined by fundamental maturational and reproductive characteristics (Charnov 1993; Kaplan and Robson 2002), for example the optimal timing of fertility termination in humans (see Hawkes 2003; Hawkes *et al.* 1998). *Sex Allocation* theory holds that parents will bias reproductive investments toward offspring generating the greatest fitness return (see Alden Smith and Smith 1994; Trivers *et al.* 1973). The *Polygyny Threshold Model* predicts when polygyny (multiple pair-bonding rather than monogamy) will occur in a population. When costs incurred are less than the benefits gained from polygynous mating (in terms of breeding quality) then polygyny will be favoured. Polygyny will affect the choice of mates by females; with a bias to those who control more resources (see Ptak and Lachmann 2003). Finally, *optimal foraging* is considered more 'middle range' theory, with models focused on the more immediate needs of an organism. Optimal Foraging Theory (OFT) in its most

simple form argues that organisms (including people) concentrate on procurement and consumption of resources (usually food), that provide the greatest rate of nutrient return (usually expressed as energy returns) while using the least amount of effort in acquisition (Bird and O'Connell 2006; MacArthur and Pianka 1966; Emlen 1966). OFT often presents generalized but realistic mathematical models relating to subsistence and social behaviour from which testable hypotheses may be formulated (Winterhalder 1981). It is related to the other longer temporal theories in that organisms are expected to switch between different strategies over variable time scales in order to maximize returns that have long-term pay offs in terms of reproductive success. That is, selection will only favour the best of feasible existing alternatives (Broughton and O'Connell 1999; Kaplan and Hill 1992:168). It is this approach from HBE that is directly applied to this research.

This thesis utilises the theoretical framework provided by HBE as it offers a robust theoretical basis based on functional explanatory frameworks, that is readily applicable to archaeological analysis. In particular, it provides a theoretical link between behaviour and fitness in populations, with known and measurable constraints.

4.2.1 Optimal Foraging Theory

Application of Optimal Foraging Theory has been applied to archaeology and anthropology over the last 20 years, particularly in North America. In Australia however, the approach has only recently been explicitly applied to archaeology (see Barton 2001; Clarkson 2004; Cosgrove 1995, 1999; Cosgrove and Allen 2000; Edwards and O'Connell 1992).

The OFT models have one basic premise: that hunter-gatherers aim to maximize the rate of nutrient return from foraging activities (Bird and O'Connell 2006; Mithen 1990:123).

With this in mind, archaeological OFT studies of hunter-gatherer subsistence and settlement can provide important insights into human mobility and patterns of landscape use. Humans, not unlike any other organism, will exploit a range of areas in the landscape in their search for somatic and/or reproductive goals. Detailed but simple models of predicted foraging behaviour can be developed by posing questions relating to these somatic goals. Such models are based on an understanding of local and more distant landscapes, their faunal and floral communities, geomorphological and geological histories, and the location of somatic goals within this landscape. These four OFT models used here are: *(i)* diet breadth, *(ii)* patch choice, *(iii)* marginal value theorem and *(iv)* the central place model.

Diet breadth

Hunter-gatherers are constantly faced with decisions regarding the types and quantities of resources they require (Lyman and O'Brien 2000). Acquisition of a resource falls into three phases: *(i) search time* – which includes all the activities that take place until the initial location of a resource; *(ii) pursuit time* – which is the period that it takes to secure the resource, and might include activities like stalking and chasing a prey; and *(iii) handling time* – the period required to obtain the energy from the resource once acquired, including activities such as de-shelling, butchering, cooking, and leaching. Often studies conflate pursuit time as a component of handling time. The strength of this model is that it can predict time spent acquiring resources and food procurement strategies as a function of time. This can then be tested through analysis of archaeological assemblages (see Bright *et al.* 2002).

The diet breadth model predicts the types of food that a forager will target. This prediction is based on the costs involved (usually expressed in terms of time) searching for, and handling a resource, which is then measured against the nutrient return the resource

offers. The model is based on an optimal diet, predicting what resources will be harvested against those that will be overlooked (Edwards and O'Connell 1995; Hawkes and O'Connell 1992:63; Kapland and Hill 1992).

The diet breadth model holds that foragers will choose to handle resources that yield the highest rate of nutrient return upon encounter, irrespective of the encounter rate for that particular resource. When higher ranked resources are not available, those resources of lower value are pursued, resulting in an increase in diet breadth (Bettinger and Richerson 1996; Bettinger 1983; Bettinger *et al.* 1996, 2006; Winterhalder 1986).

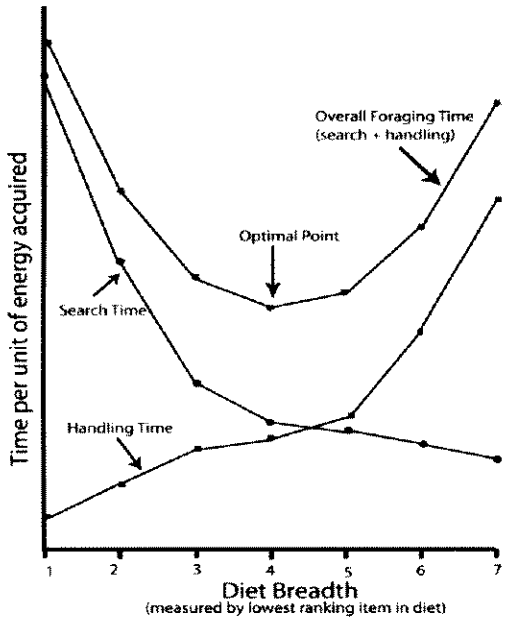

Figure 4.1: Diet Breadth Model (after MacArthur and Pianka 1966:606; Bettinger 1991) showing the relationship between energy acquired and diet breadth. Resources will be added to a diet according to the net energy return rate (as indicated on the y-axis) until the optimal point is reached (where the curve of overall foraging time is lowest). In this example an optimal diet breadth of four resources would be targeted.

Under the principles of the OFT model, it is expected that a foragers diet will be restricted and specialised where handling costs are low. If the time spent processing the highest ranking item available is low and the item is readily abundant, then there is no incentive to broaden diet. In contrast, diet becomes broader in environments where resource

procurement involves targeting lesser ranked resources, and consequently higher handling costs.

Archaeological applications

There have been many anthropological applications of the diet breadth model. Hawkes *et al.* (1982, 1987) study of the Ache hunter-gatherers of Paraguay examined diet breadth in relation to modern day foraging range. In this study it was found that the Ache had an effective foraging range of up to 5000 km^2 in which they would undertake long range trips lasting between 4 to 16 days. During these trips the time and composition of foraging groups depended on what resource was targeted. For example, groups frequently featured a sexual division of labour and included children (often using containers) (Hawkes *et al.* 1982:384). Even though hunting might occur in isolation, the group commonly shared food. When highly ranked items were encountered by the group, they were collected by all and consumed on site. While high ranked resources were always collected on these foraging trips, items with a low nutrient return or with high handling times were not targeted.

O'Connell and Hawkes (1981, 1984) completed a similar study of the Alyawarra people from the desert of Central Australia. During most Alyawarra trips they noted that only resources of high rank were taken, while grass seeds, which were readily available in the study area, were not exploited due to their high handling times.

Grayson and Delpech (1998) provide one of the few examples of an archaeological approach using the diet breadth model. They noted that the strength of this model was is its use in ethnographic applications, which were built on results of activities that are generally invisible archaeologically. Using a comparative analysis of seven ungulate assemblages from the Upper Paleolithic site of Le Lageolet I in France, the study applied the concept of ecological 'time' to archaeological 'time' averaging (Grayson and Delpech

1998:1119). Time averaging was shown to potentially change archaeological explanations of diet breadth significantly, where a maximum diet breadth and the number of taxa (NTAXA) of an assemblage might appear the same. With differential time-averaging, the longer an assemblage takes to accumulate, the greater the chance that the assemblage would incorporate a low-ranked food resource (Grayson and Delpech 1998:1123). This result presents a very important constraint upon relying too heavily on diet breadth in archaeological applications, especially when great time depth is involved.

Patch Choice Model and Marginal Value Theorem

Landscapes are not homogenous units and resources are not spread evenly through space. For this reason, the diet breadth model also considers the geographical distribution of resources. The Patch Choice Model predicts those areas a forager will search in order to maximize the rate of nutrient returns from resource when such resources are spread unevenly (MacArthur and Pianka 1966:607-9).

In its simplest form this model conceptualizes the landscape as a series of patches (areas with resources). Hunter-gatherers move around a landscape harvesting food in a predictable way. The Patch Choice Model specifies the areas where foragers should search in order to obtain the maximum return for expended effort (MacArthur and Pianka 1966:607-8). The extent to which patches are distributed homogeneously or heterogeneously within the landscape is commonly referred to as habitat grain (see Winterhalder 1980). In a habitat with a homogeneous distribution of patches, foragers will tend towards generalized use of patches, whilst in a habitat where patches are more varied, specialization will occur (Horn 1968).

Where patches are varied, those with high ranking resources spread in a predictable and evenly dispersed way will be exploited first. However as the higher ranked patches become depleted with resulting decreasing returns, lesser ranked patches will be targeted. If

environmental conditions get worse, and higher ranked patches become depleted then the patch choice model predicts that progressively fewer patches will be encountered by the forager, where once they may have targeted a more distant and better resource area.

Along with the benefits the hunter-gatherer obtains from each patch exploited, are associated costs. These include the time it takes to get to a particular patch (travel time), the time spent searching or pursuing the goal (for example prey), and the amount of time that is needed to prepare the resource for use or consumption (handling time). All of these costs will affect how many and how geographically spread out the patches are that the hunter-gatherer will exploit.

The dispersal of patches and resources sources will directly influence the location of forager settlement, principally in minimising costs of travelling to resource locations. Where food is evenly dispersed, foragers are also expected to disperse themselves across the landscape. Where food is clumped or where foragers are more mobile, settlement is more likely to aggregate (Figure 4.4).

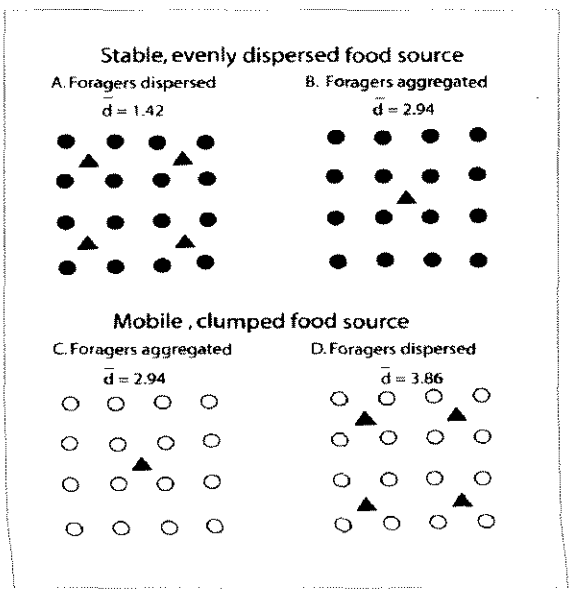

Figure 4.2: Geometric model of optimal dispersion. Settlement locations are represented by triangles and are predicted for different environments. In A and B solid circles represent stable/evenly dispersed patches. In C and D patches are clumped/mobile. The mean round-trip travel cost to the forager is given by d in each example. Travel

costs are minimised in stable patches by dispersing settlement (A), and in clumped or mobile patches by centrally locating settlement (see Horn 1968).

As different patches have different levels of productivity, so will harvesting returns. In some cases continual harvesting of a patch will have no effect on prey within the patch. If this is the case the forager will be expected to continue to exploit that patch until resource availability declines. In other instances there might be no change in prey density until the last individual is harvested, and at this point the hunter-gatherer moves on to another patch. However, these situations are rare and most commonly prey density in any given patch will decline over time with constant harvesting. The result is diminishing returns for time and labour spent exploiting the patch, which can be both graphically and empirically illustrated by *Marginal Value Theorem.*

Marginal Value Theory examines the optimal allocation of time spent foraging in a set of different patches where resources are assumed to be gradually declining as harvesting continues. There are two basic premises to this model. The first is that a forager should leave a patch when diminishing returns in that patch render overall foraging returns lower than those which might be achieved from other patches (see Charnov 1976; Stevens and Charnov 1982). Secondly, the forager will only add new patches to their harvest if the rates of return from these patches are above those for the patch currently occupied (Figure 4.5).

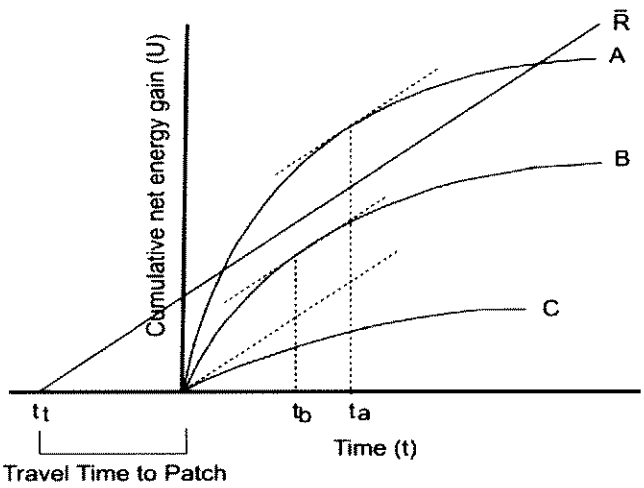

Figure 4.3: Marginal Value theorem (after Charnov 1976). The distance along the x-axis to the left of the y-axis represents time between patches. The rate of energy return (U/t) is shown by curves A, B and C. The line from t_t to $\acute{R}$ represents the total mean energy return rate for all patches. Optimal time allocation in each patch occurs at the dotted line that is tangential to the respective curve parallel to $t_t - \acute{R}$.

Archaeological Applications

Winterhalder's (1977, 1981) research of the Cree people from Ontario, Canada provides one example of how the patch choice model can be used in archaeological and anthropological research. In this study Winterhalder observed that although the Cree targeted game with calorific returns of over 1,500 cal/hr or better, the patch choice model he developed didn't work. Winterhalder had predicted that as the foraging habitat was fine grained, the Cree would have a generalized use of the landscape. In reality the Cree were very selective in their hunting behaviour. Selectivity was based largely on information exchange and learned behaviour. Winterhalder's conclusions based on the patch choice model were that humans in landscapes of even fine grain will lean towards specialization rather than a generalized foraging behaviour.

Nagaoka (2002) examined the relationship between foraging behaviour and changing environmental conditions through a foraging efficiency model, which assessed diet breadth and patch choice at the Shag River mouth site on the south island of New Zealand (Nagaoka 2002). The Shag Mouth local environment was divided into three patches - inland, coastal and offshore, and the changes in foraging efficiency were measured by indices of NTAXA (cf. Grayson and Depelch 1998).

Studies of diet change in New Zealand, such as the documented shift from the large now extinct bird – the Moa to a broad resource base, are argued to be a feature of a culture historic divide between early period moa-hunters and the later Maori (see Davidson 1984). Nagaoka's analysis shows that such a division has been too simplistic. In the initial settlement period, the inland patch was most favoured for resource acquisition, and people

may have even specialized in hunting moa. However, as the Moa became depleted, diet breadth increased. Similar trends were observed in the coastal patches, but with evidence of even broader resource exploitation than occurred inland. Lastly, as use of both the coastal and inland patches decreased, use of the offshore patch increased. Nagaoka's results both challenge the dominant culture historic divide but also show the complex nature of foraging behaviour as settlement became more mobile, dispersed and seasonal (Nagaoka 2002:438).

In Australia, Cosgrove has successfully used the *patch choice model* in exploring Late Pleistocene foraging behaviour in Southwest and Southeast Tasmania (Cosgrove 1995, 1999; Cosgrove and Allen 2001; Cosgrove and Pike-Tay 2002, 2004). Cosgrove's *diet breadth model* is based on ranking prey animals plus hunting strategies. Patterns of species distribution, element frequencies and body part representation in sites were examined as a way of determining subsistence strategies on a site and wider landscape basis. Pursuit time, ease of capture, ease of field butchery, transport and preparation; nutritional return; and incidental benefits such as raw material by-products, were all considered in this model.

Bennett's Wallaby (*Macropus rufogriseus*) and wombat (*Vombatus ursinus*) were found to be important components of the late Pleistocene economic resource base in southwest Tasmania. Both species are considered to have had similar distribution patterns throughout the region (Cosgrove 1999:387). In the southwest, stable grassland patches effectively clumped animal resources in predictable ways within valleys, and these populations were systematically exploited by humans. In contrast, the southeast local ecology resulted in the same animal resources being more scattered and distributed unevenly across the landscape (Cosgrove and Allen 2001:401).

Season-of death and skeleton-chronological studies have indicated that people were selecting particular animals of size, sex, quality and condition (Cosgrove and Pike-Tay

2002:137). Hunter-gatherers were found to have selected larger animals, particularly those over two years in age in order to obtain optimal returns (Cosgrove and Pike-Tay 2002:137). Differential transportation is recognized as a mechanism that might skew these results. Whilst female wallabies do not occur in great numbers in assemblages, it is possible that they may also have been targeted but seldom transported back to a central location. Similarly, skinning has also been considered as a process that might have occurred at a kill site prior to transport and that younger prey may have been consumed at that time. Generally however, the archaeological evidence from southwest Tasmania shows that foraging activities targeted animals in peak condition, with upland areas more intensively occupied during autumn. Foraging behaviour was focused towards logical and systematic planning that aimed to lower risk and uncertainty (Cosgrove and Pike-Tay 2002:138).

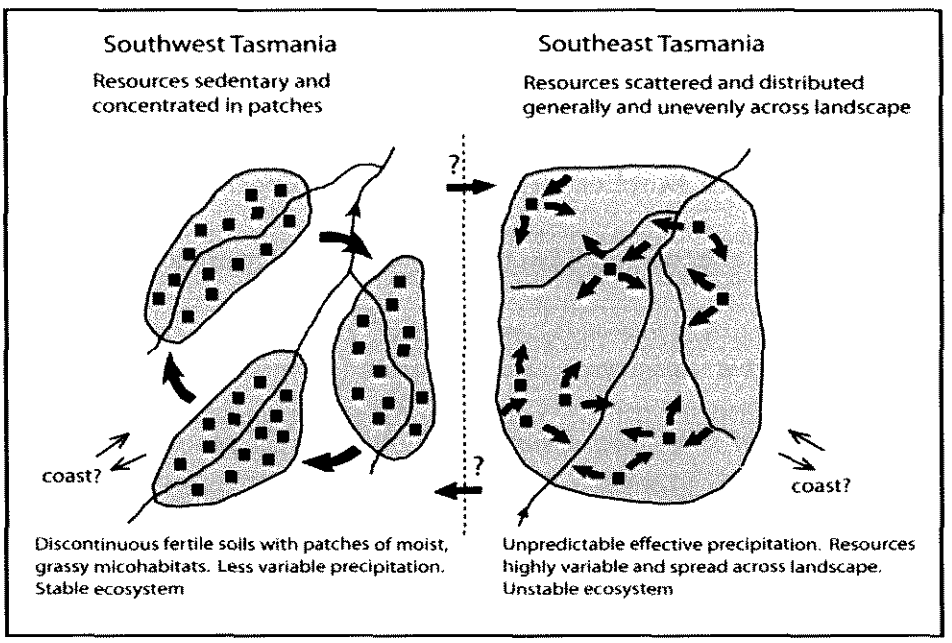

Figure 4.4: Diagrammatic depiction of foraging behaviour in southwest and southeast Tasmania (Cosgrove and Allen 2001:401). In the southwest entrenched valley systems create distinct patches (in grey) in which resources are clumped. The movement of people is indicated by the arrows. In southeast Tasmania resources are spread throughout the landscape in an uneven manner and people are more mobile and patterns of movement are less predictable.

Central Place Foraging

The consumption of resources does not necessarily take place within the patch from which they were harvested and optimal foraging theory needs to account for this complexity. The *Central Place Model* (CPM) examines the cost of bringing the consumer and resource together in time and space. CPM is based on the same marginal value theorem as described above, but adds in the cost of completing a return trip from the central place (where consumption will take place) to the patch where the resource is harvested. The cost of return trips directly effects the optimality of exploiting different patches. As the time taken to travel to a patch increases, there is a corresponding increase in the amount of time that is spent in the patch foraging and the optimal prey ranking will also increase (Figure 4.5) (Orians and Pearson 1979). Distant patches will only be exploited in two instances: when it is dictated by diminishing returns, and when the availability of higher ranked resources is greater than patches closer to the central place. It is predicted that lower ranked resources will only be targeted in proximal patches.

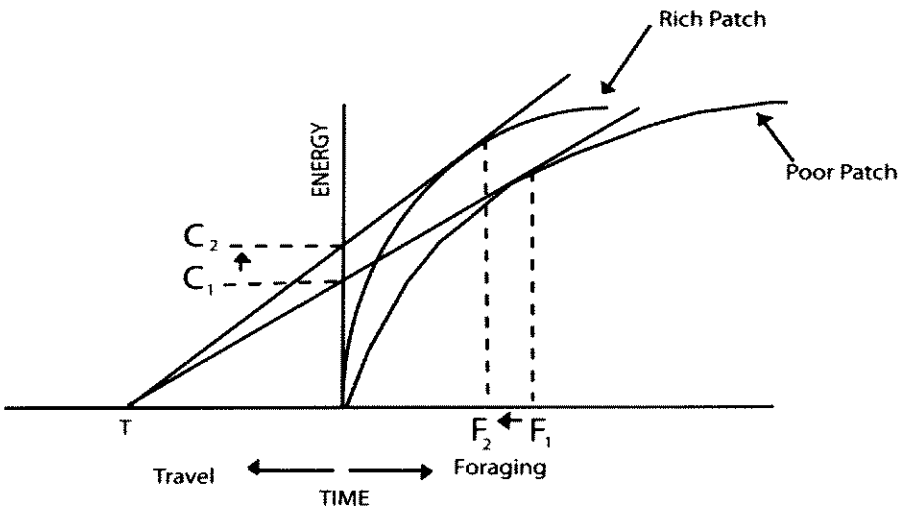

Figure 4.5: The central place foraging model (Bettinger 1991). If travelling time is constant (T) the amount of time spent foraging in patches of different value will decrease (F) and the minimum size of resources taken will increase (C).

Central Place Foraging results in greater travel time costs than foraging within local patches. These extra costs may be overcome by two mechanisms: *(i)* carrying of large loads will become increasingly more profitable with greater travel distances as it reduces the number of trips (Bettinger *et al.* 1997), *(ii)* the selection of the location where processing of resources will occur. Processing and consumption may occur at the central place, in a patch (field processing), or a combination of the two (Metcalfe and Barlow 1992; Beck *et al.* 2002; Bettinger *et al.* 1997; Metcalfe and Barlow 1992; Rhode 1990). If travel time exceeds the threshold of field processing time then it is the most efficient, conversely if it is less than field processing time the forager would be predicted to transport the resource.

As with the *Patch Choice Model*, *Central Place Model* foraging will ultimately result in resource depletion. Decisions will need to be made concerning when to abandon a patch for those that are more productive. Resource depletion can take a variety of forms, including prey relocation, changes in the behaviour of prey, over exploitation, and changes in the local habitats through land use. All resource exploitation will potentially cause declines, for example in the encounter rates of prey, leading to modifications to human foraging behaviour (Broughton 2003; Broughton and O'Connell 1999). Use of patches further away from the central place will occur once those closer are depleted (just like movement in the *Patch Choice Model*). Distant patches will be exploited based on the density and relative prey ranking of resources available.

Archaeological Applications

The *Central Place Model* has received some attention in archaeological studies, including America (Elston and Zeanah 2002; Metcalfe and Barlow 1992) and Australia (Bird and Bliege-Bird 1997). Metcalfe and Barlow have investigated forager behaviour in the Great Basin. Their study specifically examines how a trade off between field processing (allowing high utility loads to be carried), and the cost of transport was managed for the exploitation

of pinyon pine and pickleweed nut resources. (Metcalfe and Barlow 1992). Predictions were made where a trade off point between field processing and transport occurred and it was assumed that the threshold variable (z) was a graphical point on a transport-time axis where field processing would become economically profitable (Metcalfe and Barlow 1992:344). The model shows that when travel time is greater than z, field processing will occur (Figure 4.8).

For pinyon pine and pickleweed, best gains would result when foragers located camps near to the resource. However, the Californian archaeological assemblages were dominated by pickleweed. Rather than a simple preference of hunter-gatherers for pickleweed over pinyon nuts, the *Central Place Model* showed that it was more likely that pinyon nuts were field processed, whilst pickleweed was brought back to the central base. This finding has significant implications for analysis of site contents and settlement patterns, particularly as collection strategies and transport distances may not be accurately reflected in the archaeological record.

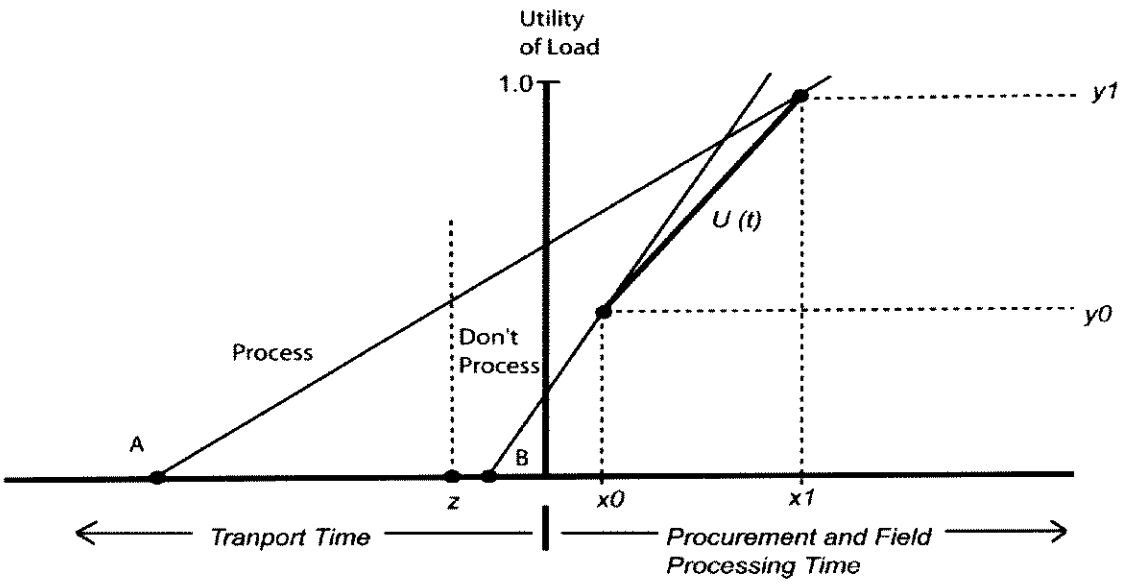

Figure 4.6: Graphic example of the field processing/transport trade off (Metcalfe and Barlow 1992:343). The area to the left of the y axis measures time taken to reach and return from patch, and the right of the y axis measures procurement of field processing time. U(t) represents the relationship between the utility of load and the time spent

procuring and processing. Where travel time is greater than "z" field processing will occur, and in situations where travel time is less than "z" no field processing will occur.

A second example of a practical application of central place foraging theory is Bettinger *et al.'s* (1997) study of acorn and mussel processing from California and the Pacific coast of North America. The authors investigated whether these two resources were likely to have been consumed on site, transported to a central place as a 'raw' resource, or processed in the field. The study is based on analysis of possible load sizes of baskets (for the acorns) and ethnographic observations of harvesting (for the mussel shells). As logistical procurement involving field processing is costly, local procurement, followed by processing at a residential base was generally preferred. In this example, reductions in residential mobility led to relocation of residential bases to locations tethered to patches where food staples were abundant (Bettinger *et al.* 1997:897).

In Northern Australia Bird and Bliege-Bird (Bird and Bliege-Bird 1997; Bird *et al.* 2002; Bliege-Bird *et al.* 2003) have applied a *Central Place Model* to their research into the foraging behaviour of the Meriam Island people from the Torres Strait. The Meriam diet includes shellfish which is harvested from reef flats and sub-littoral fringes as well as rocky shore collecting. Bird and Bliege-Bird calculated z values based on the time required to collect different species and the benefits of field processing. They found that the Meriam culled material prior to transport in order to maximise the amount of edible flesh that would be transported to a central locale (Bird and Bliege-Bird 1997:52). Large clams had low z scores and field processing occurred only at short distances from the central place.

The archaeological implications drawn from this study were:

(i) Midden assemblage composition may vary independently of prey choice. In situations where resources have high energy yields and low handling time, they are likely to be under-represented in residential deposits, whereas lower ranked species

(in this case *Nerita sp.*) will be over-represented irrespective of their dietary importance (Bird and Bliege-Bird 1997:54);

(ii) Where sites are near shellfish habitats, and shellfish have low z values, then these sites are likely to become processing or 'dinner time' camps. Sites near inter-tidal areas containing shellfish with high and low z values were considered to represent residential bases. Sites yielding shellfish with high z values some distance from collection areas might also represent residential bases.

Recently, Barton utilised a human behavioural ecological approach to his study of the surface archaeology of the Simpson Desert (Barton 2001). Barton's study aimed to determine the factors that caused hunter-gatherers to vary behaviour, the characteristics of the local ecology (and then behavioural expectations). It also attempted to establish the aspects of foraging behaviour that would be detectable in the archaeological record (Barton 2001:325).

The Simpson Desert study incorporated a number of models. A *Diet Breadth Model* was developed based on modern faunal data. Differences in resource density and location throughout the study area were compiled for a *Patch Choice Model.* Predictions for land use for individual landscape units were then made based on their structure and composition. Given the nature of the study area - surface scatters in arid Australia - sampling and analysis were necessarily confined to the stone artefact record.

The Simpson Desert artefact record was typified by expediency in design and use. However, stone artefact manufacture is argued by Barton to be a part of a broader strategy of resource use where hunter-gatherers selected technological solutions appropriate to their needs. Notably, expediency was considered as related to more than just raw material availability and reduced logistical mobility (Barton 2001:354).

Sites located at permanent springs and within sand plains of the Simpson Desert featured a diverse range of subsistence and economic activities, whilst away from these areas, group mobility was much higher (Barton 2001:332). In patches near to permanent water ,evidence of seed grinding was common and was indicative of low residential mobility. The study concluded that low densities of high ranking resources had led to expanding diet breadth and that this was reflected included stone technology (i.e. grindstones).

Archaeological patterning in the Simpson Desert was the result of repetitive or intermittent foraging on a large scale that was driven by habitat grain and patch densities. Artefact assemblages were the product of residentially mobile foragers solving problems of resource acquisition and raw material provisioning within a patchy, resource poor environment (Barton 2001:329). These strategies were not viewed as opportunistic reactions to the distribution of resources, but rather an targeted management of raw material by forward planning in location, and scheduling of artefact manufacture and maintenance.

4.2.2 Risk

The foraging models described so far, allow for predictions concerning hunter-gatherer settlement, subsistence and technological strategies through time. They also allow archaeologists to hypothesise about time management, and how hunter-gatherers balanced foraging activities against the time spent producing and maintaining tool kits, food processing, and other tasks.

In order for optimal foraging models to accurately reflect real-world situations there are further complexities that require attention. The HBE models discussed above assume fixed variables and that a forager seeks to maximise net returns. The archaeological and anthropological examples described above have illustrated that this is not always the case. The foraging behaviour of the East African Hadza and Paraguayan Ache do not seem to be aimed at short term rate maximising, and sometimes their behaviour appears totally at

odds with optimal foraging models. Also, as uncertainties exist in the real-world, the foragers' knowledge of patches and landscape not necessarily complete (Stephens and Charnov 1982). The uncertainty will cause foragers to develop a range of solutions aimed at managing risk (see Winterhalder 1986; Winterhalder *et al.* 1999). As Elston and Kuhn have commented, elements of foraging behaviour including the type and extent of mobility, diversification in subsistence, and the general notion of risk minimization are really just facets of the same general phenomenon. (Elston and Kuhn 2002:4)

Risk Minimisation

Foragers can respond to uncertainty through either risk 'sensitive' or risk 'prone' subsistence behaviour. Risk sensitive decisions aim to reduce variation in returns, whilst risk prone decisions attempt to benefit from variation. Foragers will seek to minimize the chances of falling short of resources by adopting strategies that will always yield returns that are above a critical level and with the least variance - known as the 'Extreme Variance Rule' (Stephens and Charnov 1982:258). Foragers will usually choose risk 'sensitive' behaviour over risk 'prone' as these strategies are more likely to be successful over a longer period. Strategies include changes to prey and patch choice and usage, optimal group sizes and the time spent on foraging (see Caraco *et al.* 1980; Stephens and Charnov 1982; Winterhalder 1986). Only after all available minimising strategies are exhausted are foragers expected to choose a strategy that has more variance and is risk prone (e.g. stealing resources from another foraging group).

The types of strategies that foragers will employ to combat risk are varied, but six in particular have gained attention in archaeological studies (Clarkson 2004:58): *(i)* changes to mobility, *(ii)* intensification, *(iii)* diversification, and resource sharing strategies including *(iv)* storage, *(v)* exchange, and *(vi)* group foraging (see also Bamforth and Bleed 1997).

Mobility

Mobility is exhibited in two forms: residential – where changes in mobility are brought about by moving people to resources; and logistical – where the resources are brought closer to people. Both strategies compensate for risk by reducing the spatial unevenness in the abundance of resources. They involve reduced costs in terms of travel time, increased encounter rates within and between patches, and greater sampling between patches (Clarkson 2004:59).

Goebel (2002) and Neeley (2002) have examined the relationship between residential mobility and microlithic technology. Goebel's analysis of the Upper Paleolithic archaeological record for Siberia has shown that assemblages consist of small accumulations of debitage, with ephemeral dwellings and repeated use of locations. Goebel suggests that it represents small groups of highly mobile hunter-gatherers who frequently moved their camps to patches where important animal resources were available. The nature of the flaked stone assemblages indicates that technology was organised to facilitate mobility: assemblages are characterized by high frequencies of formal tools, and microblade cores which appear to have functioned as multipurpose tools (Goebel 2002:127).

Neeley's work examines the introduction of microlithic technology and residential mobility of foragers in the Southern Levant. The adoption of microlith technology by foragers with previously high residential mobility is considered in the context of its ability to minimize transport costs whereas to become less important and allow more stable residential groups (Neeley 2002:52).

Intensification

Intensification is an overall increase in total time and effort spent foraging. The effect of intensification is to reduce variance in the supply of resources. It effectively increases the productivity of each patch rather than increasing the quantity of patches exploited. Only

those resources that yield high returns will be targeted within patches. Resources need to be relatively resistant to suppression and should not affect changes in the relative abundance of other resources (Larson 1996; Larson *et al.* 1996; Winterhalder 1986).

Winterhalder and Goland (1997) applied an expanded diet breadth model to examine the reasons for intensification in eastern North America during the late Holocene. They included the complexities of resource dispersion and the concepts of risk reduction through information sharing and exchange. Intensification took the form of prehistoric foods that displayed morphological indications of being domesticated from *c.* 4,000 BP. Two explanatory mechanisms are: *(i)* more disturbed habitats were necessarily utilised during the late Holocene, with domesticates starting as weeds; and *(ii)* plant domestication was due to changes in settlement patterns that led to local patch depletions, in turn causing increased transport distances and ultimately a decreased foraging efficiency. The consequence was an expansion in diet to include lesser ranked resources, and domesticates (Winterhalder and Goland 1997:147).

In Sub-Saharan Africa, Ambrose (2002) examined the intensification of exotic stone raw material use for manufactured for use as microliths which occurred at the end of the Middle Stone Age. Ambrose considers that this might reflect social strategies of adaptation to increased risk through "a system of reciprocal obligations mediated in part by gifts of fine-grained exotic lithic raw materials" (Ambrose 2002:10).

Diversification

Diversification enables expansion of diet breadth to include lesser ranked resources, resulting in maintenance of minimum dietary requirements. However, acquisition of lesser ranked resources will involve greater time in acquisition, handling and processing. This risk minimizing behaviour could also be coupled with risk 'prone' activities, as has been shown

by Hawkes, Bliege-Bird, O'Connell and others (see Hawkes 1990, 1991; Hawkes and Bliege-Bird 2002; Hawkes and O'Connell 1985, 1992).

Hawkes (1990), Hawkes *et al.* (2001), and Hawkes and Bliege-Bird (2002) draw attention to the ways in which meat is shared, arguing that the practice is largely due to men hunting large and dangerous game. These activities are an example of what Hawkes and Bliege-Bird term 'costly signalling' as men compete for social advantage (Hawkes and Bliege-Bird 2002:65), as demonstrated ethnographically for the African Kalahari, the Tanzanian Hadza, the South American Ache, and Northern Australian Meriam (Hawkes and Bliege-Bird 2002; O'Connell *et al.* 1988, 2002).

Kuhn (2002) has examined the coincidence between the appearance of microlith technologies and the broadening of human diets to include small game and vegetable resources in the proto-Aurignacian and the late Upper Paleolithic/Epipaleolithic, attributing it to technological diversification associated with increased diet breadth. The exploitation of new resources "placed a great advantage on the development of novel foraging techniques and subsistence technology" including microlithic technologies (Kuhn 2002:90).

Storage

Foragers may harvest greater amounts of resources than are required in order to store them for the future. Storage will effectively counter periodic resource shortages but involves large investments in terms of the time and effort expended in acquiring and processing the resources (Cashdan 1985, 1990; Low 1990). Long term storage implies a certain degree of predictive certainty, and is more prevalent in sedentary groups, often featuring intensification in procurement of certain resources.

Exchange

Establishing relationships with people outside of the immediate foraging group may also aid in minimizing risk. Exchange creates obligations for both groups, though it may provide assistance when local shortages occur. It exists in a variety of forms: *(i)* direct trade (balanced reciprocity); *(ii)* generalized exchange through the pooling of risk between larger groups; and *(iii)* theft (non reciprocal exchange). Non reciprocal exchange is a risk prone behaviour, as the ultimate consequences of taking without giving may result in negative impacts upon the foraging group. In addition to exchange of resources hunter-gatherers might exchange information, particularly if the foraging efforts might be undertaken by a group rather than an individual (Stephens and Charnov 1982).

Group Foraging

A shift from individual to group foraging will also reduce risk. Group foraging allows for greater knowledge sharing thereby reducing uncertainty in resource location. It may increase encounter rates, and reduce handling and processing times.

There are numerous benefits in group foraging. Immediate practical foraging benefits include faster patch detection time, reduced sampling time of the quality of a patch, and decreased variation in returns. There is also less chance that the group will abandon a patch prematurely. On a larger scale there are also evolutionary benefits that are associated with group foraging, including enhanced predator detection and avoidance, and increased prey capture rates. However, as Winterhalder has also noted, group foraging might not always assist all members of the group as averaging effects that reduce variance and the standard deviation of returns, can be at the expense of potential lower net return rates for the individual (Winterhalder 1986).

The relative effects of group foraging will be largely dependent upon the type of resource, i.e. frequency, dispersal, and habitat grain. For example, in ephemeral patches hunter-gatherers that forage as a group will have higher rates of return than the individual (Clark

and Mangel 1986). Where there is increased patchiness, there might be disadvantages including increased competition for resources, scrounging, and dominance effects (Packer and Pusey 1997).

The effectiveness of group foraging depends greatly on group size. Optimal group size will be determined by the spatial distribution of patches and the density and richness of resources. There are two general principles that regarding optimal group sizes: *(i)* as distance between patches increases group size becomes smaller (R.A. Barton *et al.* 1992; R.A. Barton *et al.* 1999; Janson and Goldsmith 1995); *(ii)* as patches become depleted due to the foraging activities of large groups, there will be a corresponding increase in group mobility. Other factors that will affect optimal group size include predator avoidance, infant protection, hazardous prey hunting, territoriality and opportunities for social learning.

4.6 Stone Artefacts and Optimal Foraging Theory

Studies of stone artefact technology readily lend themselves to testing optimal foraging models. At a basic level, lithic assemblages are a tangible residue of human behaviour and allow archaeologists to investigate the types of decisions hunter-gatherers made regarding subsistence activities. Whilst at a higher theoretical level, the relationship between new technological developments and the timing of their introduction and proliferation can provide valuable insights into the processes of transmission in evolutionary terms.

Changes in flaked stone technology systems are related to two primary goals: *(i)* reducing risk or *(ii)* providing the user with an increase in utility (Bamforth and Bleed 1997; Clarkson 2004, 2005; Hiscock 1994b; Larson *et al.* 1996). As with other resources, stone artefacts and their availability, production, maintenance and use can be modelled using optimal foraging theory. Three assumptions operate in these models: *(i)* technologies are needed to

extract resources from the environment; *(ii)* the context and nature of the use of patches places constraints on technological design; and *(iii)* the production of stone implements takes place within limited time and energy budgets, largely dictated by subsistence demands (Clarkson 2004:51).

With increasing foraging pressure brought about by unfavourable changes, as people modify their behaviour, pressures will also be placed on existing stone technologies and toolkits. As the objective of optimal foraging strategies is to minimize risk and maximize utility, changes to technology can greatly aid in attaining these goals. More elaborate technologies, use of different raw materials, and alternative material procurement strategies may all be implemented in order to improve success in prey capture, travel time, and in processing and harvesting (e.g. Torrence 1989).

Recent archaeological studies have been concerned with the concepts of stone raw material procurement, and tool use and discard in explaining how humans have sought to achieve gains particularly in terms of utility. The focus of these studies has primarily been on different reduction sequences and between curated and expedient tool design and function (Bamforth 1986; Parry and Kelly 1987). However, Clarkson has noted that the differentiation of technology into simple categories conflates ideas of artefact variability. Technological innovations incorporate planning and design, and lot of variability reflects emphasis on different performance characteristics aimed to enhance utility for specific roles (Bleed 1997; Clarkson 2004:66; Kuhn 2002).

Clarkson (2004) has described how the organisation of stone artefact industries can built into foraging models in terms of different provisioning and organisational strategies. These consist of: *(i)* time budgeting; *(ii)* organisation under mobility constraints; *(iii)* utility increase through design theory; and *(iv)* technological investment and gain rates (Clarkson 2004:66 and see also Caraco 1979; Kuhn 1995; Schiffer and Skibo 1987; 1997).

4.6.1 Time budgeting

As time is finite, humans have to prioritise activities in efficient ways to allow for free time to pursue activities that achieve goals, or 'enhance fitness' (see Torrence 1983). How, when and where specific tasks are undertaken all become important. For example, is stone tool provisioning undertaken at specific times within other subsistence activities or is it done separately? *Time budgeting* may have specific consequences in terms of assemblage variability and richness (Clarkson 2004:67; Hames 1992). The relative abundance of different raw materials may reflect patch visitation, and in circumstances where there is a greater amount of manufacture and maintenance in anticipation of foraging pursuits, reworking and re-use of artefacts could be expected at certain places.

4.6.2 Mobility constraints

Mobility constraints will also constrain technology. If mobility is high, then foragers would be predicted to limit tool types to specialized and multipurpose implements (Kuhn 1992, 1995; Shott 1989; Torrence 1983). In the case of central place foraging, Clarkson (2004:68) has noted that when mobility increases, raw materials will be acquired at distant locations rather than from the base. Generally, mobility constraints can be summarized as follows: *(i)* when residential mobility increases there will be a decrease in tool diversity, *(ii)* when logistical mobility increases there will be an increase in tool diversity (Clarkson 2004:69).

4.6.3 Utility increase through design theory

Improvements in the design of stone artefacts will itself often increase utility, as modifications to design can aid in solving technological problems. In this way investments in design can increase chances of prey capture or make previously unattainable resources now useful. It follows that as diet breadth increases investments in tool design and manufacture will be most profitable (Broughton and O'Connell 1999; O'Connell and Hawkes 1984).

4.6.4 Technological investment and gain rates

Stone artefacts have a limited use-life and investments which ensure that implements are more reliable and maintainable, and prolong this period will also effectively minimize risk. As a tool is used, its performance level is steadily reduced (many tools work better shortly after manufacture, and steadily decline in performance over time). Selection of appropriate raw materials and improved design are effective methods for extending the use-life of a tool (the gain rate), by producing tools which retain sharper edges, are durable, and are easily formed into artefact designs (Gould and Saggers 1985; Torrence 1989). The use-life of an artefact is also increased by tool maintenance (such as re-sharpening) performed between use periods. Different design criteria will benefit utility including: standardization, hafting, portability, versatility, and flexibility (Clarkson 2004:73-77; Fitzhugh 2001).

Standardisation of assemblages reduces maintenance time. By standardizing the features of composite tools, the costs involved in manufacturing one component will be reduced, for example stone projectile tips (Hayden 1979; Torrence 1989). *Hafting* of a tool is designed to enhance performance through utility gain, and is achieved by allowing increases in the amount of force that can be applied in the use of the artefact. The process of hafting will allow the tool to be used in a manner that would not be possible if it was not hafted. It would also increase precision and conserve stone, as fewer edges are exposed that may suffer damage (see Keeley 1982).

When mobility constraints are present hunter-gatherers will adopt strategies that are aimed at enhancing the ease of transport (*portability*), and increase the range of tasks (*versatility*). In a group with high residential mobility, a small number of larger tools would be expected. If there is high logistical mobility, the number of smaller tools would increase. Simply stated, if a hunter-gatherer has to travel farther to get food, then it is more advantageous to limit toolkits to a small number of less diverse but more complex artefacts. If mobility

changes then we should also expect changes in toolkit diversity. If foragers make long trips for specific resources then toolkits should be comprised of specialized tools rather than multipurpose tools. Consequently, versatility will be higher when tool diversity is low.

Rather than designing specific tools for specific tasks, foragers may develop toolkits that are *flexible*, where artefacts can be employed for a variety of different uses (Nelson 1991; Shott 1996). The greater the use-life, the greater the utility gain as it reduces the time and effort expended in procurement and manufacture. Where time costs are high in terms of the manufacture of the artefact, utility gain will occur only when the use-life is long enough to repay that initial investment. Generally, use-life will be improved by designing implements that are easily re-sharpened without losing too much of their edge (Kuhn 2002).

4.6.5 Provisioning Strategies

Hunter-gatherers are faced with a range of costs concerning technological investments, *e.g.* when, where and how artefacts will be used. The results of their decisions in terms of these costs will contribute to the establishment of provisioning strategies. These strategies include both provisioning of people and of places. When future contingencies are planned, provisioning provides insurance against future resource variability and availability. Provisioning can be on an individual and place specific basis.

Individual provisioning usually occurs when there is resource depletion causing more distant patches to be exploited with lower encounter rates. To be effective, tools should be portable, versatile, flexible, maintainable and reliable, and planned and manufactured in advance of use. If this is the case then toolkits will feature small, lightweight, multifunctional tool types. If there is high logistical mobility then there might also be specialization in tool manufacture, a greater diversity in tool forms, each with limited function (Clarkson 2004:65-66).

Place provisioning will occur when there is greater predictability in the location and timing of future activities (as high ranked resources are abundant and variance is low), when mobility is low, and resource patchiness is high. Place provisioning will occur when resource procurement occurs from a central place, and will be evident in transport of raw materials into the residential site and also through stockpiling of raw material with little pre-processing.

4.6.6 Archaeological Application

Clarkson (2004) provides an example of a study of technological analysis of the flaked stone was used to test utility and risk reduction models. The analysis of assemblages from four rockshelters and 293 open sites in Wardaman country, in the central area of the Northern Territory, has shown that changes in stone technology were targeted at increased utility gains and were related to effective time budgeting and embedding of activities in other tasks. People in Wardaman Country organised procurement activities during both foraging and during down-time. For example, if utility increases were to be achieved, raw materials used for artefact manufacture needed to be located and procured in patches that were being exploited, and toolkit manufacture and maintenance should have taken place in residential locations. Both features proved to have always been a feature of subsistence strategies in the region but particularly so during the last 5,000 years (Clarkson 2004:269).

Increasing technological diversity in stone artefacts also proved to be a feature of hunter-gatherer subsistence over the entire settlement period in Wardaman Country. New technological sequences of artefact types gradually appeared over the last 15,000 years, though many of these were introduced and proliferated during the last 3,000 years. Clarkson's study also found a close relationship between weight of flaked artefacts and distance from stone source evident in transported cores. Raw materials procured at distance from consumption locations were processed more intensively prior to transport.

Additionally, field processing of stone became an important feature again after 3,000 BP when cores became seldom transported, with lancet flakes specifically produced at quarries and subsequently transported.

During the late Holocene foragers used standardized artefact forms to reduce manufacturing costs associated with hafting and tool-bit replacement. For example, there was a strong reduction in variation in all aspects of shape and size of retouched implements during the last 3,000 years (Clarkson 2004:269). Hafting was also used to potentially increase utility gain, expanding function, increasing the possible force of application, enhancing efficiency, minimizing tool edge damage, and reducing the loss of small tools. Although indirect observations of this behaviour were made, no use-wear studies were completed, however the low variation in proximal width of points was suggested as a means of standardization in order to haft the implement.

Clarkson also examined portability, versatility, flexibility in design, and use-life of artefacts. A significant reduction in the size of retouched implements over the last 3,000 years was suggested to enhance portability. Versatility was characterised by a decrease in the diversity of reduction sequences. An increase in flexibility is suggested by a shift from expedient use of technologies to the use of a diverse and specialized toolkit. In the study area, sites yielded small reduced cores after 12,000 BP; larger, less reduced cores between 5,000 - 8,000 BP, and very few cores at all after 3,000 BP. The inception and proliferation of bifacial technologies and invasive retouching after 3,000 BP may reflect an increase in toolkit diversity, specialized roles and longer artefact use-life.

Scheduling, trends towards reliability and investments in technology and tool performance were all features of the subsistence strategy in Wardaman Country. Scheduling was evident in assemblages from rockshelters and large open sites in the richer land systems that acted as residential locations. A trade-off between reliable and maintainable technologies was

also noted. Reliable tools included tulas and bifacial points which occurred after 5,000 BP. Their introduction appears to have replaced scrapers (marginally retouched flakes) which were considered to be maintainable implements with short use-lives. Scrapers dominate retouched assemblages before 3,000 BP. Scrapers are also considered flexible technologies indicating investment in risk reduction prior to this time (Clarkson 2004:273). Technological investments in tool design occurred after 5,000 BP and appear to have peaked between 3,500 and 2,000 BP. This indicates a technological strategy of tool design aimed to provide better performance over a limited range of functions.

Clarkson found that changes in the abundance and structure of resources placed strong constraints on human behaviour. The differences in abundance of critical resources of water, stone raw materials, shelter, and the diversity and ranking of food resources were found to limit the time spent in patches and the range and type of technological activities.

Temporal changes in subsistence and provisioning in Wardaman Country were closely linked to changes in climate and the subsequent changes to the structure of resources. Subsistence responses included several reversals between individual and place provisioning, and major shifts in logistical mobility over time. For example at 12,000 BP there was high residential mobility, provisioning of retouched flakes and heavily reduced cores – interpreted as a low investment in manufacture (Clarkson 2004:279). During the Holocene there was a steady increase in occupational intensity with provisioning of shelters with large, less reduced cores, less reduction, and a decline in raw material diversity. Changes in climate from 5,000 BP attributed to ENSO variability, led to patchier resources and coincided with increased mobility and the development of new technologies. This period featured a massive investment in tool design, diversity, standardization and use-life. Retouched implements became more portable and were likely to have been hafted (Clarkson 2004:279-80).

4.7 Chapter Summary

4.7.1 Stone Technology and Risk

A detailed understanding of the nature of foraging activities can be gained through analysis of lithic technology. Investments in time spent on developing technological responses to will have a significant impact upon foraging behaviour. Procurement and manufacturing strategies, no matter which design criteria they address, effectively aim to diminish variation in foraging returns (Torrence 1989). Scheduling of artefact manufacturing will allow for hunter-gatherers to plan their time and hence minimize competition with foraging pursuits. Developing toolkits that are reliable and/or maintainable are crucial to maximizing the utility gain of tools over time. Effective technological strategies will feature tools that are efficient, designed to withstand stress, and easy to repair. Maintainable technologies should be standardized and quick and easy to repair/replace. Reliable technologies will be aimed to enhance performance and reduce damage thereby reducing time spent on repair and replacement.

4.7.2 Optimal Foraging Theory

Optimal Foraging Theory provides a robust theoretical framework for developing archaeological explanatory models. As OFT is rooted in behavioural ecology it provides functional explanations of behaviour with immediate and observable feedback between theory and practice.

Hunter-gatherer groups want to maximize their efficiency and success in attaining both reproductive and somatic goals. As environments change, so too will the foragers' behaviour and this will involve a range of responses. The diet-breadth and patch choice models predict that as high ranked resources become exhausted with patch depletion, a

range of return maximising and risk minimizing responses will follow. These responses will include changes to the patch choice and subsequent changes to mobility and transport.

The distribution of resources across the landscape will have important implications in reconstructing foraging behaviour. Resources may be evenly distributed, clumped or be in-between these two extremes. For example the 'geometric model of optimal dispersion' attempts to gauge both residential and logistical mobility in terms of the evenness of resources (see Horn 1966). Foragers are predicted to select an optimal settlement location that reduces travel time to resources, and thus the expected encounter rates of resources. If resources are evenly spread, foragers will exploit resources by moving their residential base frequently over short distances whilst foraging in small dispersed social units (see Cashdan 1992; Clarkson 2004:56; Smith 1983). If resources are more mobile or clustered in particular areas aggregation at a central location is predicted (Harpending and Davis 1977). Furthermore, a mixture of one or more risk minimizing strategies may be implemented such as which resources are harvested and the diversity of diet. These changes relate to somatic goals, not only food but also raw materials utilised in attaining food.

Having discussed the theory that underlies Human Behavioural Ecology and Optimal Foraging, and explained the various models and how they are applicable to archaeological studies, the next step is to develop a settlement and subsistence model for the research region that incorporates the principles of OFT and risk.

Chapter 5

Evolutionary Theory Part 2 – Human Behavioural Ecology and a Predictive Model of Hunter-gatherer Settlement and Subsistence for Riversleigh and Lawn Hill.

5.1 Introduction

This chapter builds upon the theoretical background presented in chapter 4. It applies the human behavioural ecology (HBE) approach to the physical landscape data for the Riversleigh/Lawn Hill study area and the wider Gulf of Carpentaria. The chapter discusses how the geology, topography and hydrology of the region have combined to produce the habitats and resource patches. Economically important vegetation and fauna expected to occur within these patches, and the distribution and quality of raw materials are also presented. The discussion presents a synthesis of the data in light of the HBE approach. A series of hypotheses are proposed, based upon both foraging theory and the Australian models presented in Chapter 2.

5.2 The Research Region

5.2.1 Topography

The study area can be divided into two physiographic units; a dissected plateau in the southwest and plains in the northeast (see Figure 5.1). The plains are associated with the Gulf of Carpentaria and end abruptly in the northern and central regions with vertical cliffs around 100 m high. At Riversleigh in the south, the intersection is less pronounced due to differences in the parent geology where cliffs and slopes rise up to 30 m.

The topography of the plain and plateau contrast markedly. The sediment of the plain consist of silty alluvium, black soil, and sloping colluvium. Whilst hills and mesas rise up to 30 m in places, the plain is generally flat and featureless. In contrast, the topography of the

plateau is directly associated with the underlying geology of Cambrian dolomites and is far more rugged. Here, karst topography featuring fissures and sink holes is common, and in many places there is little residual soil with surfaces of sharp limestone rocks created by carbonate removal during rainfall. Water flow through the plateau has created deeply entrenched rivers, creeks and gorges in many places and has also fashioned caverns, caves, and rockshelters.

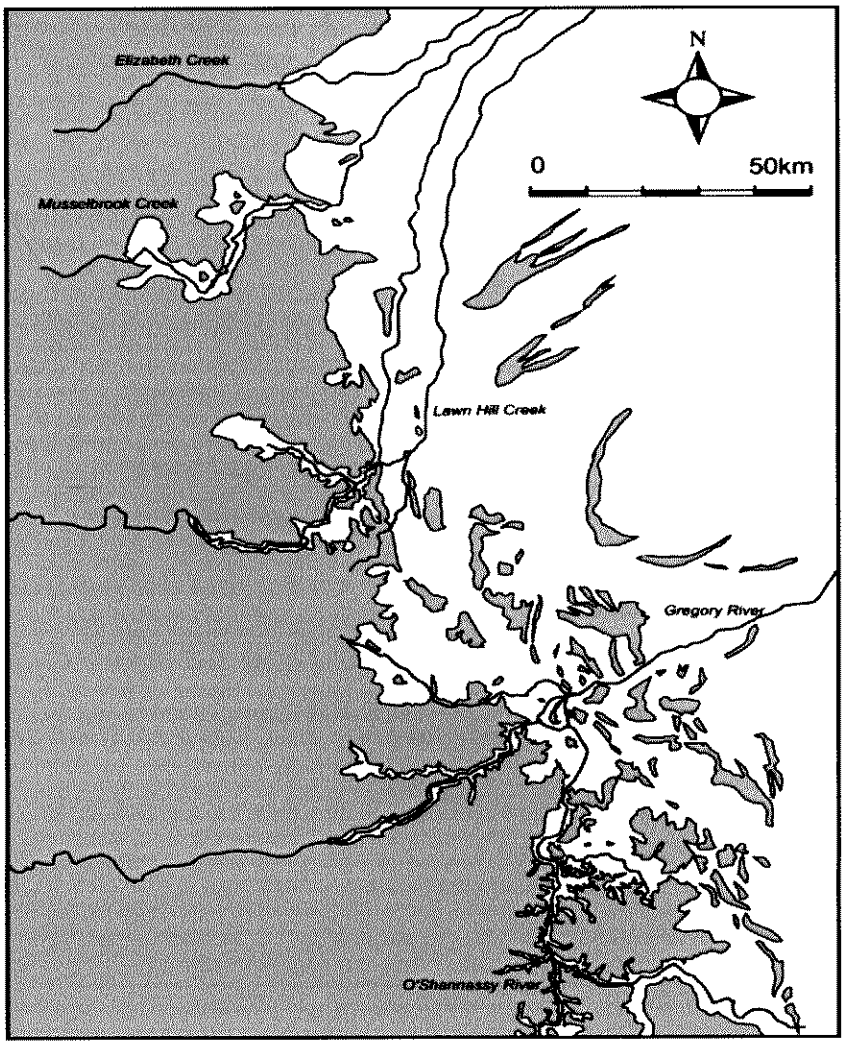

Figure 5.1: Topography of the study area. Areas that rise above 20 m in elevation are shown shaded in grey.

5.2.2 Geology

Between Mussellbrook Creek, Lawn Hill and Riversleigh the main rock types consist of Proterozoic, Middle Cambrian, and Late Tertiary formations (see Figure 5.2). Proterozoic formations include the Carpentaria, Southern Nicholson and McNamara groups, which are comprised of sandstone, siltstone and shales. To the east, the Termite Range formation, a sequence of inter-bedded sandstone, quartz-wacke, greywacke, siltstone and shale varies from 200 m to 1,100 m in thickness. In the northern study area, the Lawn Hill formation of shale, siltstone, tuff, sandstone and dolomite overlie the Termite formation. The Lawn Hill formation is overlain unconformably by a cross-bedded conglomerate named Constance sandstone. This feature forms a north-south trending scarp of dipping beds north of Riversleigh, that run for about 80 km. In the south of the research region at Riversleigh, Cambrian limestone dominates, whilst in the north immense sandstone formations are found combined with siltstones and quartzite's occurring as outcrops (Dames and Moore 1994).

In the south of Lawn Hill and Riversleigh, middle Cambrian period rock consisting of Camooweal dolomite and Thorntonia limestone, occur within the initial commencement of the karren plateau of the Barkly Tableland and associated Gregory River gorge systems. These formations overlie the Constance Sandstone and Lawn Hill formations in this area and consist of grey massive finely crystalline limestone and dolomite. This formation forms the dominant geology of the Riversleigh area.

Stone Raw Materials

There are only a few known stone types that are suitable for the manufacture of artefacts. These include: chert, greywacke, silcrete, quartzite, limestone and sandstone. All of these stone types, excluding sandstone, are suitable for flaking, whilst the sandstone is used in grinding technologies. Chert is found either as cobbles or nodules within the dolomitic

limestone of the plateau. Greywacke, silcrete and quartzite occur in the northern and eastern regions of the study area where dolomite is absent, and the sandstone formations dominate. Sandstone suitable for grinding occurs as slabs of variable size along the Constance formation and areas to the east (Figure 5.2).

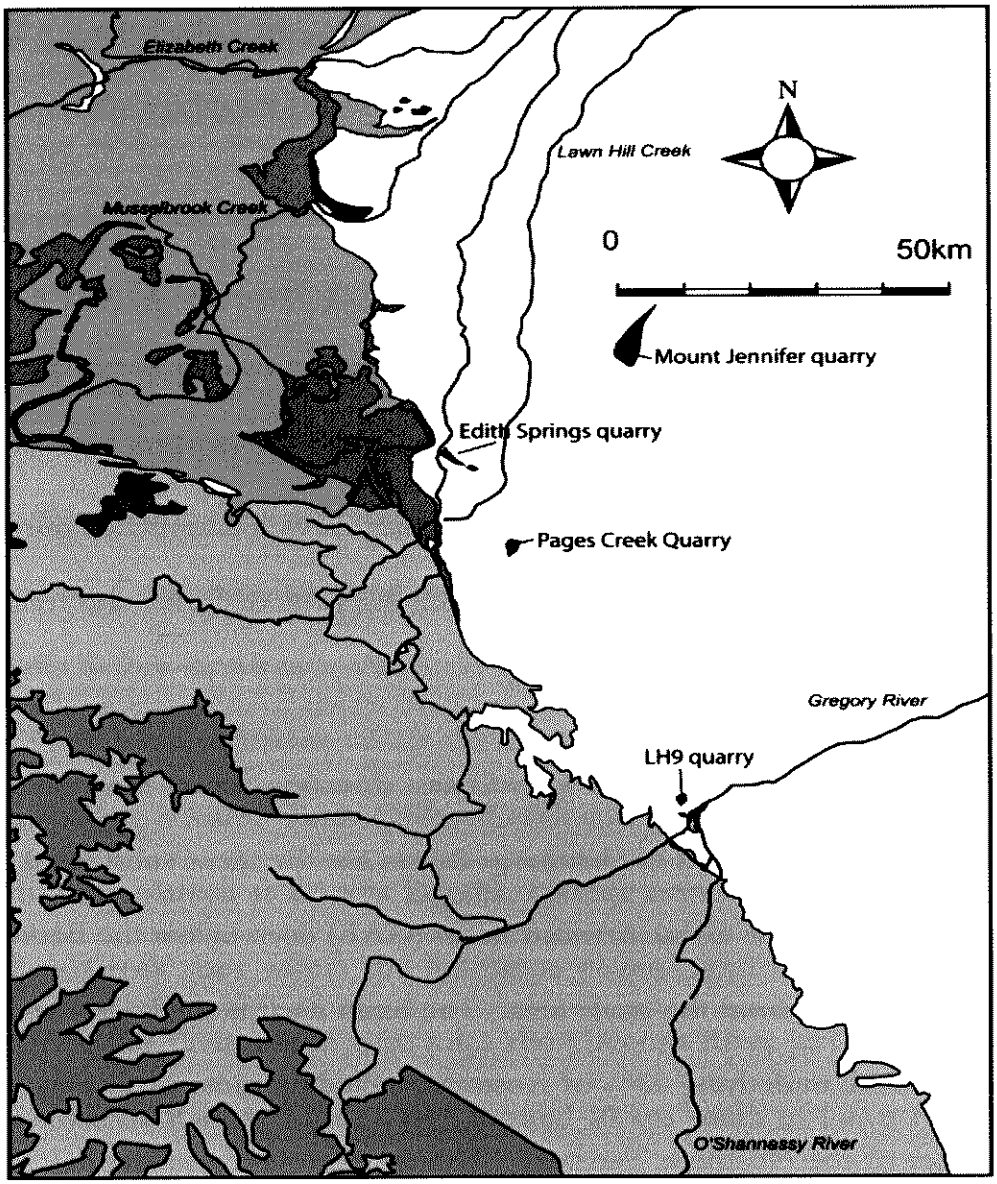

Figure 5.2: Locations of knappable stone sources within the study region. Dolomitic limestone is shown in shades of grey, silcrete sources as green, greywacke as red and sandstone is shown in orange.

5.2.3 Hydrology

The study region is wholly within the drainage basin of the Gulf of Carpentaria. The Gulf of Carpentaria is a large semi enclosed, nearly rectangular embayment occupying over 350,000 km^2 with over 2,500 km of coastline including twenty eight drainage basins. Most of the Gulf of Carpentaria is less than 70 m in depth, and in the south there is a tidal difference of up to approximately 2 km (see Rothlisberg and Jackson 1982; Hill 1994). Although arising well south of this basin, and very close to the Lake Eyre catchment, all of the water courses of Lawn Hill/Riversleigh flow northwards into the Gulf.

Rivers and Springs

The location and relative abundance of fresh water constitutes the greatest limiting factor on past Aboriginal use of Lawn Hill/Riversleigh landscape. The drainage patterns reflect the underlying geology and topography of the region. On the plateau, flat-lying limestone has led to the development of a dendritic drainage pattern with entrenched gorges and high drainage density. On the plain, drainage is sub parallel, semi-dendritic and trellised around areas of the Lawn Hill formation (Figure 5.3).

Seven permanent water courses run in a north east direction across the study region. Of these, the southern Gregory and O'Shannassy Rivers are the most substantial, rising from underground aquifers of the Great Artesian Basin (GAB) deep below the Barkly Tableland and 50 - 100 km distant from the study area. The basin itself is the largest and deepest of its kind in the world, underlying 23% of Australia, including most of Queensland and the southeast corner of the Northern Territory. The underground aquifers that make up the basin are composed of layers of quartz sandstone laid down by erosion of higher ground during the Triassic, Jurassic and Cretaceous periods and covered by marine sedimentary rock. Due to their permeability, water is able to gradually make its way through pores and eventually discharging as springs and seeps that become rivers. At their points of origin

the Gregory and O'Shannassy Rivers are at the southern extreme of the Gulf of Carpentaria drainage basin. For the first 50 km or so, these rivers constitute little more than small streams, but by the time they reach the entrenched gorge system associated with the junction of plateau and plains, they are up to 40 m wide and about 6 m deep. Once leaving the plateau at Riversleigh, the O'Shannassy River has a confluence with the Gregory River approximately 10 km into the plain. The Gregory River continues its course through the Late Quaternary alluvium and black soil plains for another 200 km until intersecting with the salt flats of the Gulf of Carpentaria near Burketown.

In central Lawn Hill there are three permanent aquifer-fed water courses: Lawn Hill Creek, Colless Creek and Louie Creek (Figure 5.3). Lawn Hill Creek commences within the Northern Territory as Carrara Creek and like the Gregory River, when it has reached the junction of plateau and plain it is wide, deep, and has created entrenched gorges. Whilst the Gregory flows only through limestone geology, at Boodja Boodja (in central Lawn Hill), Lawn Hill Creek reaches its greatest depths around the eastern most fringing sandstone cliffs before developing into a slow moving watercourse interspersed with deep waterholes. Only 5 km upstream within the limestone escarpment Lawn Hill reek is little more than a shallow stream. Both Colless Creek and Louie Creek commence at a short distance within the plateau at Boodja Boodja, and are essentially tributaries of Lawn Hill Creek. Colless Creek rises within the limestone plateau approximately 20 km north of Lawn Hill Creek and flows south east, joins the Gregory River just prior to the fringing Constance Sandstone Range. Louie Creek located 10 km south of Lawn Hill Creek, has a confluence with the Gregory River approximately 15 km onto the plains. Both creeks are shallow streams. Lawn Hill Creek joins the Gregory approximately 175 km northeast of the study area. A fourth watercourse known as Widdallion Creek, a tributary of Lawn Hill Creek splits off the main channel just beyond the transition of plateau to plain, rejoining near the Lawn Hill Creek confluence with the Gregory River. In the early 1980's

pastoralists created a weir stopping water flow into Widdallion and the creek is now dry except for a few months during the wet season. Estimates of water flow prior to this are difficult to gauge, but the presence of *Livistonia* palms attests to permanent flow.

In the north of the study area, Mussellbrook and Elizabeth Creeks, occur at 40 km and 60 km north of Lawn Hill Creek respectively (Figure 5.3). Both creeks commence about 60 km from the junction of plateau and plain and flow into Lawn Hill Creek near to its confluence with the Gregory River. During the 'dry' season Mussellbrook and Elizabeth Creeks cease to flow and are reduced to a series of large waterholes, averaging 2 km in length and up to 40 m wide.

Along the upper watercourses of the central and southern rivers and creeks (Colless, Lawn Hill, Louie Creek and the Gregory and O'Shannassy Rivers) there are numerous formations of tufa that alter water flow. These tufa formations are the result of calcium carbonate deposition and are strongly influenced by high evaporation, warm water temperatures and aquatic insect larvae (Carthew *et al.* 2003, 2006). In many places the tufa effectively interferes with water flow, following the development of pools, waterfalls, rapids and expansive shallows. Tufa dams occur on the Gregory River and in some places are substantial, creating shallow pool areas of up to 1, 200 m^2. The tufa formations along both Louie Creek and the Gregory River have been investigated geomorphologically and some of the tufa sequences have been carbon dated (Drysdale 1999, 2001; Drysdale and Head 1994, 1998; Taylor *et al.* 2004) (Table 5.1).

Sampling Site	Sample Code	Age (year BP) (uncorrected)	Age (year BP) (corrected)	Sample context
Carl Creek	OZF88	3,150 ± 40	505	shells from sedimentary fill upstream of fossil dam series
Carl Creek	OZF860	3,410 ± 40	765	shells from sedimentary fill located between fossil dam series
Carl Creek	OZF861	3,880 ± 40	1,265	shells from sedimentary fill on the downside side of a fossil dam sequence, underlying a fossil tufa dam
Armchairs	OZF859	11,940 ± 70	9,295	shells from sedimentary fill upstream from fossil tufa dam
Armchairs	OZF862	45,000 ± 1200	42,355	shells from sedimentary fill directly behind fossil tufa dam

Table 5.1: Age data for fossil tufa sequences at the Carl Creek site and the Armchairs site at Riversleigh (from Carthew *et al.* 2006:94)

In addition to permanent rivers and creeks, permanent and semi-permanent springs occur within the study region. These are particularly prevalent at the edges of the Constance Sandstone in the central and northern study areas. Resistant sandstone commonly forms a natural barrier across watercourses, where the localized springs often fill substantial pools of fresh water. Such springs include Hartness, Gorge, Edith, and a number of unnamed springs. To the south of the Constance Range a single spring known as Jirringirri (Lilydale Spring) is known.

Ephemeral creeks and streams

The region's variability in weather conditions means that during the 'dry' season water is generally not available on either the plateau or plain, other than from the permanent rivers and creeks. Unseasonable rainfall may result in small pools, which soon dry out. In

contrast, during the 'wet' season heavy rainfall fills abundant pools, small creeks and creates waterfalls in the limestone and sandstone gorges.

On the plains 'wet' season, rains create plentiful stocks of standing water. Large creeks are filled and during periods of excessive precipitation ephemeral creeks often flood. However, when the 'wet' season finishes water-flow on the plains soon diminishes, with most large ephemeral streams ceasing to flow within a few weeks. For a month or so, waterholes may occur along such streams, but they too are soon dry.

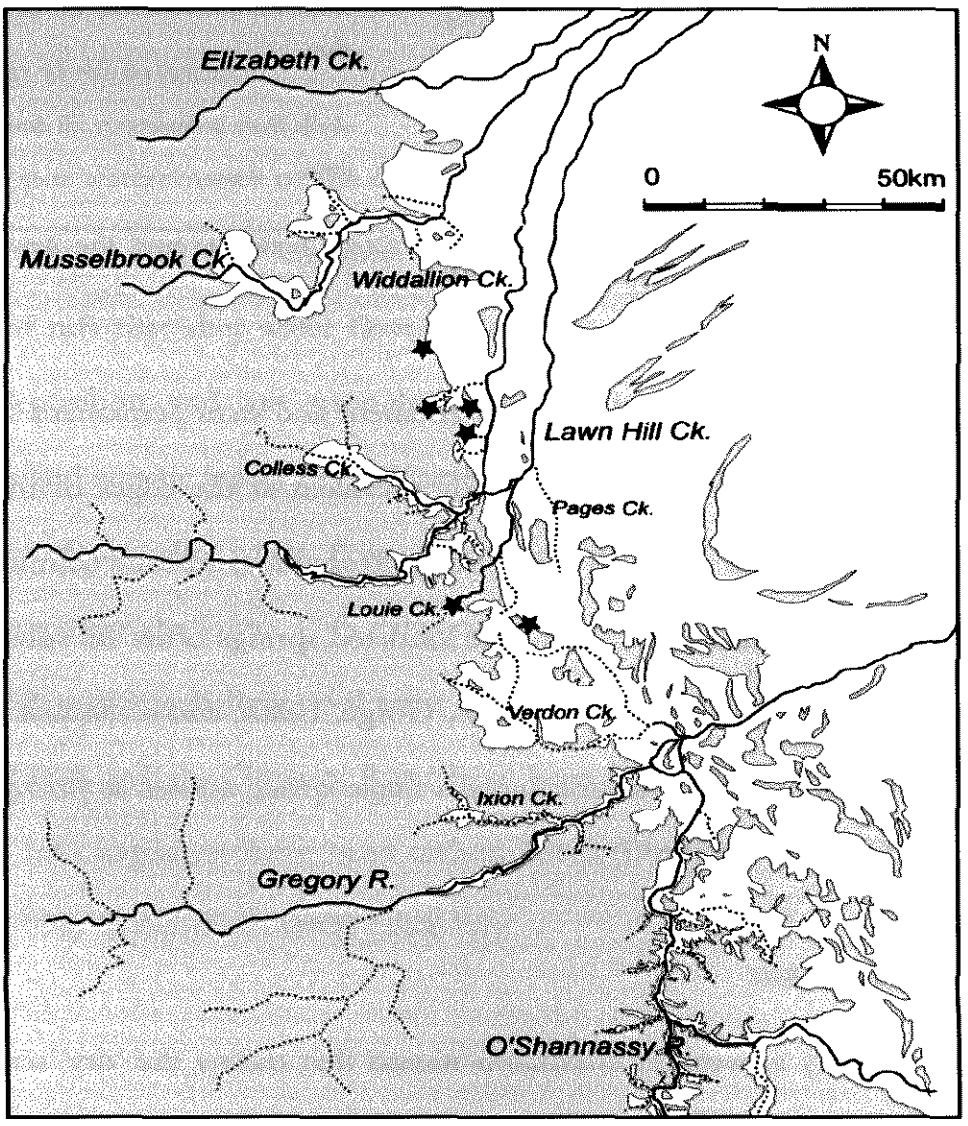

Figure 5.3: Hydrology of Riversleigh and Lawn Hill. northwest Queensland. Permanent rivers are shown as solid blue lines, ephemeral streams as dashed blue lines and springs are indicated by red stars.

5.2.4 Climate

Regional

The regional climate plays a crucial role in location and predictability of resources. The climate of the Gulf of Carpentaria region is strongly seasonal and is dominated by the Northern Australian – South East Asian tropical monsoon, characterised by marked seasonal variations in prevailing winds, temperature, and rainfall patterns. Between December and March there is a pronounced short wet season due to the effects of tropical monsoons originating in South East Asia and in Northern Australia. Generally dry conditions exist during the rest of the year due to the Inter-Tropical Convergence Zone (ITCZ) moving north of the equator and resulting in dry south east trade winds dominating the weather of the Gulf of Carpentaria. However the El Niño Southern Oscillation (ENSO) effect can result in large variations in the timing and amount of seasonal rainfall in the wet season. The onset of ENSO can vary, from the failure of the wet season to a very strong rainfall and tropical cyclone activity. Between October and November a transitional period occurs and is characterised by thunderstorms at irregular intervals prior to the onset of more general rain systems.

Study area

Although the climate of the tropical north and Gulf of Carpentaria greatly affect the local climate, there are pronounced regional differences. Intraregional variations would have been far more pronounced at different times in the past. In general, average rainfall decreases with increasing distance from the coast of the Gulf of Carpentaria. Within the research region rainfall levels vary considerably. In the Lawn Hill central area the climate is better described as semi-arid rather than monsoonal. Mean rainfall is about 350 mm at Lawn Hill station during the peak three month period of November to February and is less decreases further south. During the 'wet season', thunderstorms and tropical depressions

(originating to the northwest) can effectively soak a few hectares whilst no rainfall occurs in other areas (Dames and Moore 1994). Due to the nature of the entrenched gorges of the plateau, thunderstorms can also result in significant increases in stream flow through gorges in a very short time. As a result, there is scouring of sediments adjacent to rivers, and in some areas flooding can also occur. On the plains numerous ephemeral streams experience strong flows and flooding at this time, and pools of water are present on low lying deflated rocky areas.

During the long and pronounced dry season between March and October, it is unlikely that any precipitation will occur. At this time the only available water is found in the perennial rivers of the Gregory and O'Shannassy Rivers, and Lawn Hill Creek. Stagnant but extensive pools or 'billabongs' occur on Mussellbrook and Elizabeth Creeks. Any shallow pools of free water on gibbers only last about a week after rain, and ephemeral streams although flowing strongly after storms, dry out within weeks.

As with rainfall, average temperatures vary greatly during the year, peaking in the wet season with an average daily maximum of 38°C for January, although it is not uncommon to experience temperatures between 40-48°C. High temperatures combined with elevated humidity and sometimes heavy rainfall makes Lawn Hill/Riversleigh an isolated and barely tolerable place to be at this time.

During the remainder of the year (March – October) temperatures remain generally high with an average maximum temperature of 25°C. Overnight temperatures do not usually drop below 10°C. During the dry season, evaporation exceeds precipitation and the only surface water available is from the perennial river systems.

5.2.5 Vegetation Communities

Given the immense size, geology and hydrology of the study region a number of distinct vegetation communities occur. The primary factor determining the type and extent of such communities is proximity to permanent water. The region is generally classified as consisting of a mix of low open woodland, grassland and riparian vegetation communities. However, a number of additional local vegetation communities occur within these broader units. These communities consist of riverine and riparian corridors, woodlands and grasslands (see Dames and Moore 1994; Milson 2000a, b).

Within areas like the gorges and on the plain close to permanent rivers vegetation is dense and diverse. In such areas, a combination of parent rock, alluvial sediments, and water-flow determine biodiversity. It is not unusual to have areas of low open woodland, open forest, closed forest and patches of rainforest within only a few hundred metres of each other.

Community 1 - Riverine and riparian corridors

Riverine and riparian corridors are found along the course of each of the main permanent rivers and creeks of the study region. They are also a feature on intermittent creek lines, although vegetation is less dense than along permanent creeks. Within the gorges, fringing riparian forests line all of the main water courses. The presence of permanent water and much deeper soils than any other vegetation community, allow trees to grow up to four times larger than elsewhere. *Livistonia* palms and *Pandanas* dominate the river banks.

Along the intermittent streams and waterholes, vegetation is dominated by *Eucalyptus camaldulensis* (River Red Gum), which grow to 10 m in height. Away from waterholes *Terminalia canescens* (Winged Nut Tree) dominates. Some of these areas also feature dense stands of *Acacia farnesiana* (Mimosa) and *Melaleuca*. Along the banks and within the water of the most substantial rivers (and particularly within gorges) there is a diverse vegetation

featuring *Marsilea angustifolia* (Narrow Leaf Nardoo), *Ottelia alimoides* (Lily), *Pandanus aquaticus* (Palm Tree) and *Nymphaea gigantea* (Giant Water Lily).

Figure 5.4: Riparian community along the Gregory River, northwest Queensland.

Community 2 - Woodlands

Low open woodlands dominated by *Corymbia terminalis* (Western Bloodwood) cover most of the area distant from water at Boodjamulla. Woodlands occur on both the plain and the plateau, but are most dominant on the plain up to about 1 km from permanent water. This community usually consists of an upper layer of *Eucalyptus terminalis* (Western Bloodwood), *Terminalia hadleyana* (Wild Peach), *Lysiphyllum cunninghamii* (Bauhinia), *Brachychiton australis* (Hill Kurrajong), *Gyrocarpus americanus* (Helicopter Tree), and *E. pruinosa* (Silverleaf Box). A mid-storey dominant layer of *Senn glutinosa* (Silver Cassia), *Lysiphyllum cunninghamii* (Bauhinia), and *Terminalia aridicola* (Arid Peach) also occurs (Dames And Moore 1994:55-5). The ground layer consists of mixed grasses, herbs and vines. A further sub-group of this community occurs specifically in association with steep and lower dissected foot-slopes of the Carpentarian sandstone formation. It is dominated by *E. leucophloia* (Snappy Gum) and

T. aridicola subsp. *Aridicola* (Arid Peach) and an understorey of *Triodia pungens* (Soft Spinifex).

Figure 5.5: Woodland community, Gregory River, northwest Queensland.

Community 3 - Grasslands

Beyond the open woodlands, black soils and rocky outcrops associated with the underlying geology have created sparsely vegetated areas of grassland. This community is dominated by groundcovers of grasses especially *Triodia pungens* (Soft Spinifex). In some places even this is absent, such as in areas of exposed parent rock, and particularly on the plateau within the Thorntonia limestone where skeletal soil and barren rocky ground are found, and do not permit the growth of much vegetation. In these areas small *Acacia* (Wattle)

trees are the only plants present including *A. holosericea* (Soap Bush) and *A. hemiglauca*. Vegetation is also very sparse on the tops of the fringing sandstone ranges, consisting of *E. dichromophloia* (Bloodwood), and *E. aspera* (Desert Bloodwood) with ground cover consisting of various spinifex grasses.

On the plain, grasslands occur on flat to gently undulating areas where poor soil quality and exposures of rock occur. The deep cracking soils and weak gilgai development of the plain are dominated by very tall grasses with occasional emergents, dominated by *Astrebla squarrosa* (Mitchell Grass), *Chrysopogon fallax* (Ribbon Grass), *Dichanthium sericeum* (Queensland Bluegrass), and *Aristrida hygrometrica* (Northern Kerosene Grass). The clumped and spreading nature of these grasses provides a continuous low-level canopy. However, there are considerable bare areas at ground level. Where the soil is shallow and the ground rocky, there is tall open *Triodia* (Spinifex) hummock grassland with isolated trees.

Figure 5.6: Grassland Community, Riversleigh, northwest Queensland.

5.2.6 Faunal Communities

The faunal communities of the study area are closely linked to the geology, topography and hydrology of the region. Previous environmental surveys have identified seven different faunal communities that are broadly coincident with particular vegetation communities: riverine/riparian, alluvial flats, boulder outcrops, limestone, woodland, grassland, and spinifex hills (Dames and Moore 1994:59). Habitats have been defined with respect to vegetation, topography and soils, and are also affected by the distance to permanent water, the presence of flowering trees, fire regimes and ground cover. In some areas human activities such as pastoral industry, the construction of weirs, and introduced species (cattle, pigs and cats), have also created artificial habitats.

Birds constitute the most diverse and abundant fauna for the region (135 species). Of these 72 species are considered residents, 53 are nomadic and 7 are migrants. Although about 65% of birds are widely distributed, the population densities are highest in the woodlands, riverine/riparian corridors and on alluvial flats. Numbers increase during the wet season, especially when local flora such as *Eucalyptus pruinosa* are in bloom attracting many species of honeyeaters. Populations of the fifty most common resident birds vary between 200 and 5,000.

Nineteen species of mammals have been recorded within the study region - fifteen native and four introduced species. Greatest mammalian diversity is found on the plateau and within the gorges, largely due to the numerous species of bats. Some mammals have particularly restricted habitats (*i.e.* water rats), whilst others can be found in all environmental communities. Desert dwelling mammals such as the Western Hare Wallaby are only located on the plateau areas, whilst the Agile Wallaby which occurs in great numbers on the plain and riparian corridors, is not found at all on the plateau. In total, five species of macropod have been identified in the region including *Macropus rufus* (Red

Kangaroo) *M. robustus* (Euro), *M. agilis* (Agile Wallaby), *Onychogalea unguifera* (Northern Nailtail Wallaby), and *Lagorchestes conspicillatus* (Spectacled Hare-Wallaby) (Dames and Moore 1994:56).

Other fauna of the study region include 49 species of reptiles: nine geckoes, four legless lizards, six dragons, three monitors, 17 skinks, 3 pythons, and 7 venomous snakes (Dames and Moore 1994:61). Woodlands are the favored vegetation zone for 25 species of reptiles. Limestone and boulder outcrops also sustain numerous populations of reptiles. Permanent rivers support stable populations of *Crocodylus johnsoni* (Freshwater Crocodile), *Emydura subglobosa* (Painted Turtle), *Elseya dentata* (Northern Snapping Turtle), and numerous snakes.

In addition to some reptiles, the rivers and pools of the study area contain 12 species of frog plus the introduced *Bufo marinus* (Cane Toad), aquatic invertebrates including *Hemiptera* (True Bugs), *Coleoptera* (Beetles) and *Cheumatopsyche* sp. and *Chimarra* sp. (Caddisflies), micro-crustaceans such as *Macrobrachium* sp. (Giant Freshwater Prawns); and 29 species of fish including *Ariidae* and *Plotosidae* (Catfish), *Lates calcarifer* (Barramundi) and *Haphaestus fulignosus* (Sooty Grunter).

No Species	Riverine	Alluvial Flats	Boulder Outcrops	Limestone	Woodland	Grassland	Spinifex Hills
mammals	7	6	7	7	10	8	3
amphibians	13	5	0	3	3	2	1
reptiles	12	12	21	18	25	11	14
birds	77	78	24	50	99	47	14
Total Species	**109**	**101**	**52**	**78**	**137**	**68**	**32**

Table 5.2: Faunal richness of each of the different vegetation zones for the research region.

5.2.7 Ethnohistory

Early ethno-historic observations describe the nature of settlement and subsistence around the time of first contact between Europeans and Aborigines 1865-1880 (Slack 2002).

Details of the size of Aboriginal groups and the places where they were encountered by Europeans in the study area show a strong correlation with archaeological evidence. In almost all instances, early accounts state that Aborigines were observed along the creek banks and always within close proximity to permanent water. For example, an article in *The Queenslander* newspaper described Edkin's Lagoon in the north of the study region as "a favourite camp of the blacks, judging by the great heaps of mussel shells piled up on its banks" (anon 1878). Caroline Creaghe, an early explorer of the region described the construction of wet season shelters: "There were four humpies made of coarse grass growing all around, bound together with strips of bark. They are built in a semi – circle, all open. It is only during the rainy season they inhabit them, in fine weather they lie in open country under trees…" (Creaghe 1883).

Details of subsistence activities include descriptions of Aboriginal hunting and gathering technology. Creaghe described holes cut out of trees from which she assumed possums and native bee honey (sugar-bag) were obtained (Creaghe 1883). At the junction of the Gregory and O'Shannassy Rivers she also described in detail the remains of a deserted camp site where "large heaps of ashes were also everywhere along the banks; also large quantities of kangaroo's and emu bones, fish and freshwater crocodile bones etc" (Creaghe 1883). A scientific correspondent named Sutherland who lived near to Burketown observed hunting technology that consisted of elaborate large nets "long and wide, very neatly made and strong, the fibre being chiefly from the bark of the Kurrejong (sic)" that were placed at significant tracks leading from the edge of the rivers in order to catch kangaroos and emu. Dilly-bags and fishing lines were also made from bark of the flax

plant twisted in either one or three strands, with a hook usually made from the wishbone of a bird rasped on one side to a sharp point and barbed (Sutherland 1913). Another method for fishing involved construction of a thick rope "about as thick as a mans thigh" from grass, that once stretched across the river was used by Aborigines to scare fish by swinging it in the water driving the fish into a weir, where they were clubbed (Sutherland 1913).

Using fire to manage the landscape appears to have been an important part of Aboriginal subsistence. Explorers often described large areas of the region as having been burnt shortly before their arrival, and that local Aborigines practiced intermittent burning (see Carruthers 1885 in Van der Meer 1998; Sutherland 1913).

In 1897 anthropologist Walter Roth published *Ethnological Studies among the North – West – Central Queensland Aborigines* (Roth 1897; see also Roth 1904) and although no specific reference to the people of the study area is made in this book it provides a general synthesis of the practices and material culture of the northwest Queensland Aborigines. Roth specifically details material culture of the neighbouring Kalkadoon and Indjilandji people describing hunting and food preparation, domestic implements, 'fire-stick' farming, ornamentation, trade networks, and ceremonies. Roth carefully described artefact types, sources and the technology of production for the whole of northwest Queensland.

Artefacts

Roth (1897) described both wooden and stone implements from the Leichhardt-Selwyn region to the south east of the study area. These artefacts include fighting and hunting, domestic, and ceremonial implements. At least three different types of boomerangs were recorded; ornate, fluted (longitudinally) and plain. According to Roth a variety of wooden spears were known for the region, including 'acicular' and 'spatulate' tipped hand spears, woomera spears and stone tipped spears (Roth 1897:247). The throwing stick or 'nulla

nulla' was also observed by Roth close to the study area (Roth 1897:256). Other artefacts noted by early ethnographers include edge-ground stone axes and a variety of stone knives made from what is referred to as blade flakes hafted into 'cementing substance' to form a handle.

Domestic artefacts included storage and transportation vessels, woodworking, and food preparation implements. Coolamons are well known throughout the study region both ethnographically and observed in the field. Used to carry water or food they were manufactured from a piece of concave bark cut from the trunk of a tree or branch. A great diversity in coolamon size and shape exists as they were often cut at the time of need to perform a specific task. Aboriginal informants note today that coolamons could be up to 2 m in length, with attached handles and carried by several people (J. Diamond pers. comm. 2004).

Another tool Roth specifically refers to is the 'native chisel' describing it as being "one of the most useful tools in the possession of the aboriginals, and universal throughout North-West-Central Queensland" (Roth 1897:149). Consisting of a 'flint' flake hafted at either end of a short smoothed piece of timber, it is used for a variety of tasks including the maintenance of wooden spear tips, as a cutting implement and to prepare hides. Roth's 'native chisel' is essentially a retouched flake, hafted and subject to regular re-sharpening.

Grindstones have been noted consistently across the semi-arid/arid region of northwest Queensland. They consist of a flat sandstone slab - a lower stone slab and a smaller upper stone, often referred to as a muller which can be round or flat. Also noted by Roth were 'baking ovens' (Roth 1897:156). Baking involved a large fire to heat stones, moving the hot stones into a hole, and then placing the meat on the stones. Another layer of hot stones would be placed on top of the meat, followed by a skin and final covering of mud.

Personal Ornamentation, ceremony and trade

Roth describes the use of feathers, bones and grasses as either temporary ornaments such as belts and headdresses, or as decorative semi-permanent jewellery with piercing. Also described are the practices of avulsion of the central upper incisors, and scarring of the body (Roth 1897: 109-113). Photographs taken at Riversleigh at about 1905 provide the only record of Aboriginal ceremonial practices and adornment. They show elaborate headdresses worn by males, with shields and swords (see Figure 5.7).

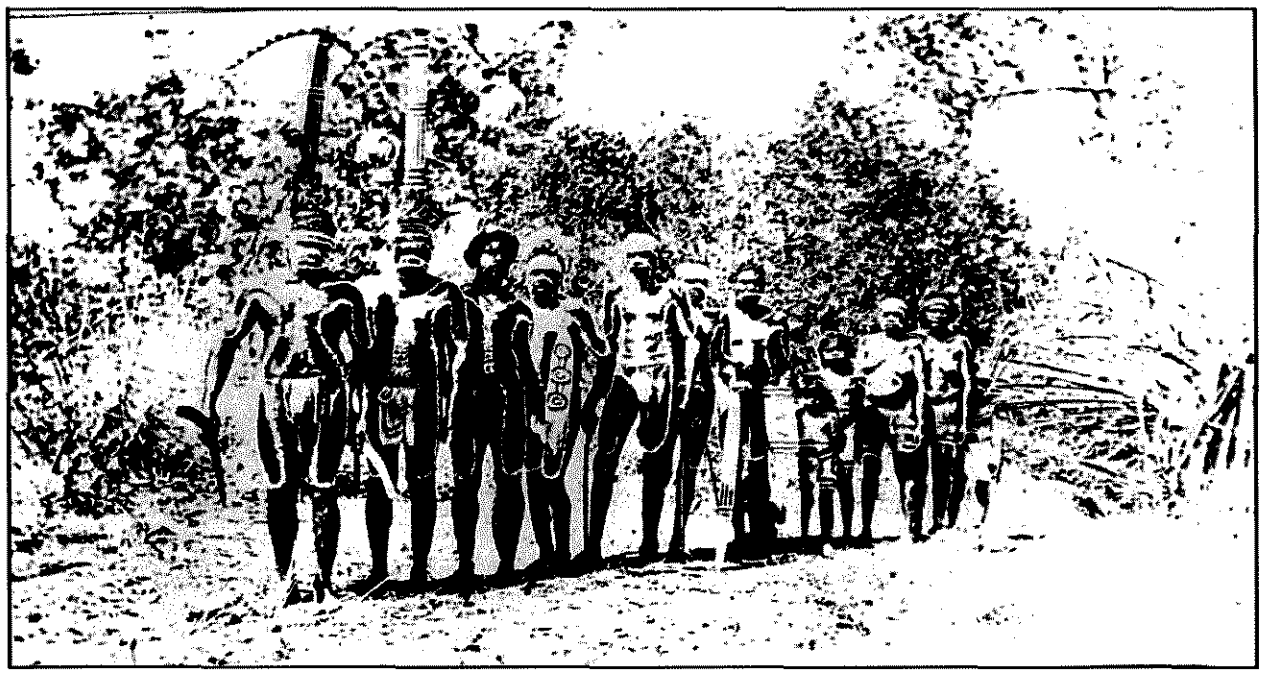

Figure 5.7: Aborigines at Riversleigh station, northwest Queensland c. 1910 showing elaborate headdresses, shields and boomerangs.

Roth detailed extensive trade networks throughout northwest Queensland, and meetings in 'markets' at places such as the head of the Georgina River and Lake Nash approximately 400 km to the southwest of the study region. *Duboisia hopwoodii* (Pituri) is known to have been extensively traded from Carlo on the eastern edge of the Simpson Desert into northwest Queensland (see Mulvaney and Kamminga 1999:278). In the study, area red ochre from Jirringirri (Lilydale Spring) is known historically to have been an important

trade item with Aboriginal groups up to 250 km away (S. O'Keefe pers. comm. 2003). It is likely that trade was an important part of Aboriginal social life at contact, especially to the southwest and northwest. An exception is the Kalkadoon People of the southeast where oral history only makes mention of hostilities with the Waanyi people (E. King pers. comm. 2002). However, in contrast to the ethnographic explanations of a lack of trade with the Kalkadoon, hundreds of edge ground axes are commonly found in Late Holocene contexts throughout the study area. Hiscock has previously suggested that the closest raw material suitable for manufacture of such artefacts comes from Kalkadoon country at Lake Moondarra near to Mount Isa (see Hiscock 1988:55).

Early ethnographies sometimes detail important observations concerning the methods of prey capture (e.g. the methods of fish capture discussed above). These observations may have implications in respect of search, handling and capture times for prey. This in turn will effect the development of prey rankings when developing expected diet breadth models.

5.3 Riversleigh / Lawn Hill Model of Subsistence and Settlement

This section outlines a model for human foraging behaviour developed for the research region. It incorporates the environmental data discussed above, current knowledge concerning climate changes over the last 50,000 years (see Chapter 2) and expected foraging behaviour stemming from the theoretical predictions of human behavioural ecology (Chapter 4). The model includes predictions emanating from the diet breadth and patch choice models, but includes other elements of HBE including marginal value theorem and central place foraging theory. The responses to risk and uncertainty are then explored in respect of both resource use and lithic technology through time.

5.3.1 Diet Breadth model

The first stage of developing a model of foraging behaviour for the study region is to examine diet breadth. Diet breadth for the study area is based upon a combination of personal observation, vegetation surveys, ethnographic literature and previous research in Northern Australia. Personal observations have been made throughout the course of six years of fieldwork in the study area. During fieldwork the location and suggested uses of foods by Traditional Owners has been noted. Aboriginal diet in the nineteenth century in the region was varied and included seed and root vegetables, fruit, flowers and honey, in addition to local fauna. A list of observed Aboriginal plant foodstuffs and their use that applies generally to the study region is detailed below in Table 5.. The list implies that a variety of plant foods were probably targeted by foragers in the research region. However, as organic remains rarely survive in the archaeological record, many of these plants would not be visible, though investigations of microfossils such as pollen, starch or phytoliths may provide valuable supplementary data.

In relation to faunal material, the development of a diet breadth model requires establishing prey rankings. Rankings are usually based on a combination of the energy returns of any given resource in terms of the energy required to harvest (search, capture and handling times). Development of prey rankings requires a detailed level of field observation and analysis of the calorie values of many specific resources. Clarkson's (2004) dissertation provides the only recent attempt at a comprehensive diet breadth model for Australian prehistoric foragers for the Central Northern Territory, and the model was compiled from various sources (Table 5.3).

Taxa	Common Name	Aboriginal Use
Livistonia rigida	cabbage palm	growing bud eaten raw or cooked
Vitex glabrata	black plum	fruit eaten raw or cooked, wood used for fire sticks
Lysiphyllum carronii	bauhinia	sap eaten, drink made from flowers
Brachychiton collinus	kurrajong	seeds roasted, tap root and gum eaten raw, bark for string
Ficus sp.	fig	figs eaten, leaves as sandpaper, medicinal
Flueggea virosa	white berry bush	seeds eaten raw, ground to paste, cooked as damper
Cyperus vaginatus	rushes	fruit eaten raw, medicinal, tuber starch
Ipomoea sp.	bush potato	eaten raw, tuber
Pandanus aquaticus	pandanus	edible tubers
Eucalyptus terminalis	western bloodwood	seeds roasted, leaf base eaten raw, medicinal, leaves for fibre, trunks for rafts
Grevillea striata	grevillea sp.	galls eaten, drink made from flowers, sugar bag, sap medicinal
Hakea arborescens	corkwoods	drinks made from flowers, seeds eaten, medicinal
Carissa lanceolata	konkerberry	berries eaten
Carissa ovata	currant bush	berries eaten
Triodia pungens	hummock grass	resin used for hafting stone artefacts
Cochlospermum fraseri	kapok bushes	flowers and roots eaten
Santalum lanceolatum	sandalwood	fruits eaten, medicinal
Grevillea mimosoides	grevillea sp.	drinks made from flowers, seeds eaten
Boerhavia sp.	tar vine	taproot eaten (tuber)
Cissus rebiformis	native grape	fruits eaten
Portualaca aleracea	pigweed	seeds, stems and leaves eaten
Marsilea exarata	nardoo	Toxic starchy sporocarps ground with water and cooked into damper
Owenia acidula	emu apple	fruits eaten

Table 5.3: Aboriginal Plant Use for the research region (after Wrightman and Andrews 1991).

Resource	hr/kg	Kcal/kg	Kcal/hr	Rank	Reference
			high ranking		
Edible Fruit	0.07	3980	56857	1	(Bird *et al.* In Prep; O'Connell and Hawkes 1981)
Eggs	0.10	3000	30000	2	(Clarkson 2004)
Gum	0.21	4147	19748	3	(Bird *et al.* In Prep; O'Connell and Hawkes 1981)
Snake	0.17	3000	17647	4	(Hawkes *et al.* 1982)
Slow Terrestrial Animals	0.17	3000	17647	5	(McCarthy and McArthur 1960)
Terrestrial bulbs	0.26	3326	12792	6	(Cane 1984)
Shallow Burrowing Animals	0.25	3000	12000	7	(O'Connell and Hawkes 1984)
Arboreal Animals	0.26	3000	11538	8	(O'Connell and Hawkes 1984)
			medium ranking		
Medium Sized Mobile Prey	0.28	3000	10714	9	(Hawkes *et al.* 1982; Jones 1982)
Large Aquatic Animals	0.30	3000	10000	10	(Hames 1979)
Honey and Larp	0.46	4147	9015	11	(Devitt 1988; Hawkes *et al.*1982)
Turtles	0.46	3000	6522	12	(Hawkes *et al.* 1982)
Birds	0.26	1640	6308	13	(Hawkes *et al.* 1982)
Shallow Rooted Non-Toxic Tubers	0.25	1563	6252	14	(Hawkes *et al.* 1982)
Deep Burrowing Animals	0.5	3000	6000	15	(Clarkson 2004)
Toxic Nuts	0.53	2000	3774	16	(Jones 1980)
			low ranking		
Deep rooted Non-Toxic Tubers	0.50	1563	3126	17	(O'Connell and Hawkes 1981)
Fish	0.46	1370	2978	18	(Hawkes *et al.* 1982)
Larvae	0.46	1318	2865	19	(Hawkes *et al.* 1982)
Aquatic Tubers	0.70	1145	1636	20	(McCarthy and McArthur 1960)
Freshwater Mussels	0.72	800	1111	21	(Jones 1980)
Fallen Grass Seeds	3.70	3450	932	22	(Cane 1984)
Tree Seeds	5.70	5190	911	23	(Cane 1984)
Grass Seeds (*Poaceae sp.*)	6.00	3450	575	24	(Cane 1984)
Palm Heart (*Livistonia mariae*)	0.66	270	409	25	(McCarthy and McArthur 1960)

Table 5.4: General Diet Breadth Model for Northern Australia (Clarkson 2004). Resources have been ranked on the basis of their Kcal/hr returns after costs have been accounted for.

The diet breadth model (like Table 5.) charts the relative rankings of food resources from highest to lowest. The highest ranked foods are generally those that are easily obtained and require little preparation. For example, Clarkson's diet breadth model predicts that edible fruit is the highest ranked and most preferred resource. Foods that are either difficult to obtain or are of low calorie return are lowest in diet ranking. For example, both grass seeds and palm hearts have extensive time costs for processing, while freshwater mussels are of comparatively lower energy return compared to most other resources.

There are a few concerns with establishing a diet breadth model as per Clarkson's example. Firstly, is the issue of applicability of data. Many of the studies that have been used to formulate the data in Table 5.4 are based on short term observations of forager behaviour drawn from environments that do not always provide effective parallels for Australia generally or this region. Secondly, some rankings are based on very old research (*i.e.* McCarthy and McArthur 1960; Jones 1980). A third and even more crucial concern is that some of the measurements of the rates of energy returned do not reflect the data obtained from studies. For example, the energy return rates and subsequent placement of edible fruit in Clarkson's model appears to exaggerate its value. According to discussion by O'Connell and Hawkes (1981) it is more likely that fruit would return about 5,000 kcal/hr. This same paper details a higher value for arboreal animals of approximately 6,000 kcal/hr.

Use of ethnographic literature provides a more robust resource ranking system, as well as greater understanding of resource acquisition technologies that may not be visible in the archaeological record. For example, the ease of prey capture and the travelling time to resources are important factors in the relative value of resources. Technologies that reduce either of these factors might shift lower ranked foods higher up in a diet breadth ranking system. For example, fish are relatively low in resource preference in Table 5.4; however techniques such as netting and poisoning that are not visible archaeologically involve far

less energy expenditure for possible large scale returns. Similarly, group foraging and the use of string nets to trap emus will also reduce effort of capture of this highly mobile prey. Roth (1897) details that such techniques were developed to cope with fauna with high levels of encounter uncertainty, and low success rates with species such as dingoes and macropods. Techniques to counter uncertainty included group foraging, hunting in the middle and hottest part of the day (to catch sleeping prey) and in the example of trapping birds even using a lure of a grasshopper on string (Roth 1897:137).

One particular resource worth considering in more detail are freshwater mussels. The shells are one of the most abundant finds in archaeological deposits at Lawn Hill/Riversleigh. The technique for obtaining them is to dig by hand in the mud of the river bank and at Riversleigh it is known that most of these mussels are buried up to 1 m in depth. Foraging of shellfish with their very low kCal/kg ratio and low diet breadth ranking therefore may have been a highly exhaustive physical process for little energy return.

Archaeological testing of a diet breadth model in this region really requires local data rather than more general studies derived from other locations. In the absence of direct quantitative data concerning different energy return rates for the Riversleigh/Lawn Hill study area it has been necessary to develop a far more general model of diet breadth than the one offered by Clarkson (2004) in Table 5.4.

The diet breadth model presented here is based primarily on field observation and discussions with Aboriginal informants. It ranks resources based purely on their energy return and Aboriginal preference, regardless of their ease of capture, handling times etc (Table 5.5). Observations have shown that the preferred foods are without doubt those that provide large energy returns (calories). Large mammals (usually kangaroo) and reptiles (goanna) are preferred. These are followed by medium and smaller mammals and reptiles, turtles and fish. Foods such as fruit have a lower ranking at this initial stage.

Ranking	Resource
1	large mammals and reptiles
2	medium mammals and reptiles
7	honey
4	large birds (turkey)
5	turtle
6	fish
7	medium birds (only a few species)
8	fruit
9	eggs
10	mussels
11	tubers
12	seeds

Table 5.5 **Prey Ranking for general classes of food at Lawn Hill/Riversleigh based on personal observation and discussions with Aboriginal survey members**

Male Aboriginal survey team members were clear that they favoured large mammals and reptiles to eat. However, as noted previously, these foods often involve less frequent encounter rates and lengthy capture times. In contrast, some foods that the diet breadth model in Table 5.4 rank highly were not favoured at all by Waanyi informants. These included arboreal animals (mainly bats), tubers and seeds. Aboriginal people had an attitude that these foods might be eaten only when everything else had been exhausted. Some foods were considered either taboo to consume or not worthy of the effort, as with bats and seeds. Another complexity is that most food collection is historically known to have been done by women. Today most of these foods have been replaced by European items in the Waanyi diet making it difficult to gauge their prior importance. However, during survey 'down time' it was noted that women frequently used this time to either fish, or to collect fruit and berries.

A basic diet breadth model was developed after the nature of foraging, including capture rates and ease of resource handling, incorporating the first stage of prey rankings (Table 5.5). The top three resources in this model (honey, fruit and eggs) would be predicted to

be harvested every time they are encountered during foraging. All are easy to obtain and provide very high calorie returns for minimal effort. In the case of honey it is commonly extracted using no more than a thin stick placed into a bee – hole on the side of a tree. Following these higher ranked resources are those that are commonly associated with hunting activities. Unlike Clarkson's inversion between large and small mammals, this model acknowledges that minor technological innovations (including complex weaponry and snares) as indicated in ethnographic accounts, would have eliminated the distinction between large, medium and small game. It is more likely that Aboriginal people would have targeted each of these indiscriminately.

The lower ranking foods in the Lawn Hill/Riversleigh diet breadth model are those that require extra skills or extensive physical exertion to be acquired. Fishing for turtle and other aquatic resources requires skill and patience (but might be conducted during 'down – time' from other active resource procurement). Mussels and tubers often involve exhaustive digging to obtain and large quantities to satisfy hunger. Seeds also require large harvest quantities and are time consuming in terms of processing.

Ranking	Resource
1	honey
2	fruit
3	eggs
4	large mammals and reptiles
5	medium mammals and reptiles
6	large birds (turkey)
7	large aquatic animals (turtle)
8	fish
9	medium birds (only a few species) freshwater mussels
10	arboreal animals
11	tubers
12	seeds

Table 5.6 **Prey rankings/diet breadth model for main food resources in the Lawn Hill/Riversleigh study area.**

5.3.2 Stone Artefacts and Foraging

The previous chapter discussed the ways in which stone artefacts can be imbedded into foraging models and earlier in this chapter descriptions of raw materials and their location were outlined. By far the most dominant raw material in assemblages is chert, which is available as river cobbles or as nodules in limestone in either the gorges or on the plateau. The location of chert corresponds positively with the location of the primary sources of water and the high productivity patches (woodlands and riparian). In contrast, raw materials including greywacke and silcrete are located in areas that are further away from permanent water and within less productive patches, specifically the grasslands and plateau.

Investigating the relationship between flaked stone technology and foraging activities at Lawn Hill/Riversleigh involves examination of: *(i)* levels of raw material procurement and transportation relative to availability and quality of materials; *(ii)* changes in discard rates in archaeological sites within different patches; *(iii)* changes in the type and intensity of reduction through time; and *(iv)* the level of toolkit diversity over time.

Stone Procurement

The patterns of stone raw material procurement are indicative of the foraging strategies of a population. Diversity and relative abundance of raw materials provides information concerning patch visitation and the overall mobility of foragers. Differential transportation of raw materials, distance decay and the relative occurrences of field processing are also significant.

Within the study area there are two main types of raw material procurement that are expected. Local chert is expected to have been acquired predominantly from river cobbles and to a much lesser extent from quarry areas on the limestone plateau. Although chert sources are very close to areas that are predicted as residential bases for a population, it is considered likely that initial reduction of stone took place at the sources and cobbles or

quarried stone brought back to a site might already be quite heavily reduced (see Hiscock 1988:157-60). Extraction of chert is likely to have been embedded into other tasks and also occurred during 'down - time' (Torrence 1983).

Procurement of other more distant stone raw materials is expected to be different to chert. As greywacke stone sources are located on eastern grasslands, and its acquisition is therefore predicted to have taken place as specific tasks and also opportunistically during hunting in marginal patches. It is expected that most reduction of greywacke would take place at the source location.

Discard Rates

Occupation intensity is measured by the level of artefact discard throughout the region. The approach is the same that has been taken to analysis of other material including fauna and charcoal. Not withstanding taphonomic effects, the level of artefact discard in sites may be a useful measure of the intensity of the site occupation. Assuming a low population density the more artefacts, the more intensive/frequent the occupation. Discard rates are quantified by weight, number, artefact classes and then assessed relative to other independent measures of occupation intensity including sedimentation rates and breakage (due to treadage).

Reduction

Reduction sequences are examined in order to focus on use-life as an indicator of technological strategies. A particular technology is aimed at extending the life of an artefact, and as a pay-off for costs associated with design and manufacture, thereby enhancing utility gain. Given that access to raw materials is not uncertain or difficult, there seems no need to conserve raw materials, at least in areas in proximity to water (and within gorges). Different reduction sequences are therefore more likely to directly relate to the

manufacturer or users solutions to problems concerning both environmental uncertainty and selective pressures.

Reduction sequences utilised in stone artefact manufacture and maintenance were assessed by analysis of all types of debitage, cores, flakes and retouched flakes. Cores were quantified by assessing the extent of core reduction. The attributes of this analysis included the number of rotations, the prevalence of parallel flake scars and the incidence of single or cortical platforms. The frequency of different retouched artefact implement types was also used to evaluate whether extensions to tool use-life were related to greater levels of foraging stress brought about by less stable environments (Hiscock 2001a, 2002a, 2006). Lastly, given their dominance in assemblages, unmodified flakes have received detailed study including changes in overall average dimensions, *i.e.* pointedness, length – width, and weight. The types of terminations, the proportions of flake platform types and the extent of their preparation were also recorded (see Andrefsky 1998; Dibble 1997, 1998; Dibble and Whittaker 1981; Flenniken and White 1985; Shott 1996, 2003; Shott *et al.* 2000; Speth 1981).

Technological diversity

The level of technological diversity in hunter-gatherer societies is directly associated with subsistence strategies. Diversity is limited by transportation and mobility costs and the relative levels of task specificity that lithic material might be used for. Technological diversity will be lower where there is high residential mobility. However, if there is a high level of logistical mobility, specialized tools will occur, thereby inferring greater technological diversity. Increased logistical mobility is one solution to greater resource patchiness, and more mobile resources. If technological diversity increases then it is expected that the increase in the number of tool types will also provide utility gain rates. Recent research has documented increasing levels of technological diversity in the

Australian Holocene record, where continuums of change have been identified. These include flakes, scrapers, cores, lancets, burins, points, burrens, tulas, grindstones, axes, to leilira blades (Attenbrow *et al.* 1995; Clarkson 2004, 2005; Hiscock 2002a; Hiscock and Attenbrow 2002, 2003; Law 2005).

5.3.3 Mobility and lithic assemblages

Three types of sites are predicted to occur within the study region: *(i)* residential bases, *(ii)* short term camps, and *(iii)* limited activity areas. Each of these site types reflects strategies of residential mobility, both spatially, and temporally, and are directly related to the patch model.

Residential bases

Residential bases are locations where a full range of subsistence activities took place and where hunter-gatherers focused their lives. These sites will contain diverse lithic assemblages that are large and coarse grained with high levels of variation and complexity (see Nelson 1991). As stone raw material sourcing is embedded in the forager's subsistence system, then we would expect residential bases to contain a wide variety of stone material types and qualities, and possibly large heavy items of site furniture *e.g.* grinding stones (Binford 1979, 1980). Given the amount of time that is spent in these locations, residential bases should also feature high frequencies of worn and broken artefacts, larger assemblages of flake debitage and extended core reduction.

Short term camps

Short term camps are located away from residential bases, e.g. correlate to hunting activities, occurring as dinner-time or overnight camps (Barton 2001:162; Cane 1984, 1987; Nicholson and Cane 1991). These sites will be common during periods of high residential mobility (Nicholson and Cane 1991; Yellen 1968). While the artefact assemblages at these

places will be similar to the larger bases, they will feature limited diversity and complexity. Assemblages at short term camps are largely determined by the amount of material that foragers are able to carry, and as such, it is likely that there will be evidence for curation of tools, and that debitage will relate more to maintenance activities rather than tool production. It is also predicted that short term camps will feature task specific items such as backed artefacts.

Limited activity sites

Limited activity sites are places where resource extraction took place, e.g. butchering locations or stone raw material sources. Unless these places were often visited, they are expected to be of very low archaeological visibility consisting of small lithic assemblages of broken, or retouching debitage in places where tools were used for resource extraction (Binford 1980; Thomas 1983). Such materials may also feature prepared cores that were use to manufacture 'expedient tools' on site.

5.3.4 Riversleigh/Lawn Hill Patch Choice Model

Based on the above descriptions of environmental units, and the location of critical resources within them a patch choice model for Riversleigh/Lawn Hill has been formulated. This model operates on both a local and regional basis.

Local Patch Choice

The study area has been divided into four different local patch types based upon a synthesis of the vegetation, contemporary faunal communities and the geology of the region: *(i)* Riverine and Riparian; *(ii)* Woodlands; *(iii)* Grasslands; and *(iv)* Limestone Plateau.

Each patch type occurs as an uneven environment, though they are spatially predictable. The level of predictability may have varied considerably over long and short timescales. In

the same way that vegetation is patterned so too is the location of fauna within patches. For instance, freshwater aquatic resources are only available within a riverine environment. The highly ranked honey and fruit will only be found consistently within woodland patches (due to the prevalence of suitable trees), and to a lesser extent in the riverine and riparian patch. Small, medium, and large animals all have home ranges with some species having specific habitat types, *e.g.* Euros are only recorded in the spinifex hills and on the limestone plateau. The ranges of most mammals include numerous local patch types. For example, macropods will venture into riparian patches for water, whilst spending other periods in woodlands and grasslands. Although this aspect of their behaviour complicates a patch model assumes mammals spend most of their time in woodlands patches due to harsh conditions in other areas (grasslands and limestone plateaus) and competition and danger along rivers (personal observation).

As the geographic spread of food resources is known, descriptions of each patch for the study region and the foods located can be compiled.

Riverine-Riparian

The riverine-riparian patch occurs along most of the primary permanent watercourses and is particularly dominant along areas within the gorges that occur along the plateau at Riversleigh. On the plains riverine-riparian corridors occur much less often and more randomly, usually associated with large areas of standing water (c.f. tufa dams). The Riparian element of forms a corridor of variable width, 10 - 200 m and contains a high biodiversity in a fine grain habitat. Aquatic and terrestrial animals and economic plants feature, including the highest ranked resources - fruiting trees and honey. Stone raw material sources within this patch type occur as cobbles in banks and shallows of rivers. The riverine-riparian patch may also be present within semi-permanent water-courses;

however during periods of increased aridity, the patches in these environments would have soon become depleted.

The riverine-riparian patches would have provided a focus for human settlement and subsistence throughout the occupation of the study region. Evidence of human occupation will be concentrated within this patch type as residential bases. However, within the gorge areas it is expected that a range of site types occur including rockshelters, shell middens, and art panels will occur. Evidence of stone artefact procurement and manufacture is expected to be manifested as quarried riverbanks and shallows, small chert quarries along limestone ridges and scatters located on the periphery of the patch.

As the riverine and riparian patch is expected to have been a focus for extended residential base camps it also follows that it would have been a place from which central place foraging trips would have been made. Due to the richness of the patch, long distance foraging is only expected to have been made for high ranked or rare items.

Lithic assemblages from sites within the riverine-riparian patch will feature extended core reduction, evidence of tool production, maintenance and repair with high ratios of flakes to tools and broken tools to complete tools, with provisioning of some locations with raw material. It is likely that artefacts with evidence of use reflect expedient tool use for on site tasks, as evidenced by a large number of unretouched flakes. Where curated items do occur it is likely they will be heavily curated and discarded by the forager replacing worn items in toolkits.

Woodlands

Woodlands occur along primary permanent watercourses on the eastern plains of the study region and on smaller alluvial plains located within the periphery of gorges associated with the plateau. Woodlands contain the highest levels of biodiversity and are directly

associated with proximity to permanent water, beginning at the transition from riparian communities to a distance of up to approximately 500 - 1,000 m. This patch type.

The location, extent and richness of the woodland patch would have been highly variable over time. During periods of high annual rainfall, the patch was extensive with a fine grain habitat. During extended periods of aridity, woodland patches would have contracted significantly with minor encroachments on the riparian corridors. Habitat grain is expected to have been significantly patchier during such periods.

The woodlands, similar to the riverine and riparian areas, would have provided a focus for extended periods of occupation during phases of enhanced rainfall. During phases of more arid weather, occupation is likely to have been short term. It is quite likely that during wet periods central place foraging may have occurred from these places, then when a particular patch became dry, higher levels of group mobility would have resulted. Overall, the woodlands patch is expected to show evidence of a mixed mobility strategy and generally intensive use. However, a distance decay effect would emerge as the density of archaeological discard is expected to be significantly reduced with distance from permanent water.

Site types that will occur within this patch type will be strongly correlated with local geological and hydrological conditions, but are expected to include stone artefact procurement and manufacturing locations as well as instances of artefact discard due to breakage during use. Such sites have been shown to have a possible antiquity of over 10,000 BP based upon lithic weathering patterns (see Hiscock 1988). Sites that include evidence of food consumption as either residential bases or as single events might also occur within this patch. However, due to the harsh taphonomic conditions of the study area they are unlikely to be of any great antiquity.

The lithic assemblages in woodland patches will show evidence of extended core reduction in areas near to water and raw material sources, and will depend on the extent of nearby riverine patches and the location of Woodlands with respect to water, stone sources and natural shelter. Where woodland patches are near to these resources they should feature high rates of tool discard, moderate levels of tool diversity and perhaps higher frequencies of grindstones around areas close to free-standing water. It is also possible that certain locations may be provisioned with stone raw materials. Where woodlands are situated in regions that are further removed from critical resources, the expectations are that site frequency, size, richness and diversity will be far lower.

Grasslands

The grasslands patch type is a combination of boulder outcrops, spinifex hills and black soil plains, which occurs predominantly on the eastern plains of the study region beyond woodland patches. It also occurs on the limestone plateau abutting the limestone plateau patch, and at great distance from permanent water.

Grasslands contain low levels of biodiversity and are a coarse grain habitat. Fauna consists predominantly of reptiles, birds and larger mammals. During periods of increased rainfall this patch might have offered temporary enhanced richness as other local species expanded their range. However, in all but the wettest of conditions these patches exhibit low richness. It is unlikely that foragers utilised this patch with any intensity, and that use was limited to resource extraction and foraging during periods of wet weather. Archaeological sites that are expected within the patch include stone quarries including greywacke, isolated artefacts discarded during hunting trips, and isolated art in boulder outcrops and on the more significant mesas that outcrop in the northern area of the study region and are closer to permanent water (see Border 1988). Except at quarry locations, the predicted stone

assemblages of this patch will display little or no evidence of tool manufacture, low diversity and be comprised primarily of discard of worn and broken artefacts.

Limestone Plateau

The limestone plateau patch consists entirely of the western and southern parts of the study region and dominate the southwest Riversleigh area. The patch consists of Cambrian and Tertiary limestone, with little residual soils and vegetation. Increases in rainfall and aridity are expected to have had little effect on the patchiness or richness of these areas. This patch is of low biodiversity and therefore low habitat grain and is generally depauperate in resources. The foraging use of the limestone plateau area is expected to have been very similar to the grasslands patch and would have primarily been used for targeting medium and large size animals and larger reptiles. Some areas near to the edge of the plateau may have been used as quarries to extract stone raw material, particularly chert. Besides these localised areas, this low use patch is expected to only feature a low frequency of broken and worn artefacts.

Regional Patch Model

In addition to the local model, the study area has been divided into two regional ecosystem types consisting of the southern Riversleigh and the northern Lawn Hill ecosystems. There are marked contrasts in the nature of these parts of the study area. Riversleigh is dominated by the Gregory River, a permanent aquifer fed river that is seasonally stable, connected and more substantial than the rivers of the north. Tufa deposits also occur on the Gregory River at Riversleigh and create large dammed areas of free-standing permanent water which remains for hundreds of years. A result of this stable water flow is that local level patches have had greater longevity resulting in their substantial size and are finer grain. In the north at Lawn Hill, Musselbrook and Elizabeth Creeks water flow is less predictable. Some of the creeks are seasonal and by the middle of the dry season they

cease to flow and exist as a series of billabongs. In the north, patch composition is different in terms of extent and grain, and resources are more scattered and less predictable. In addition, stone raw material sources are more distant.

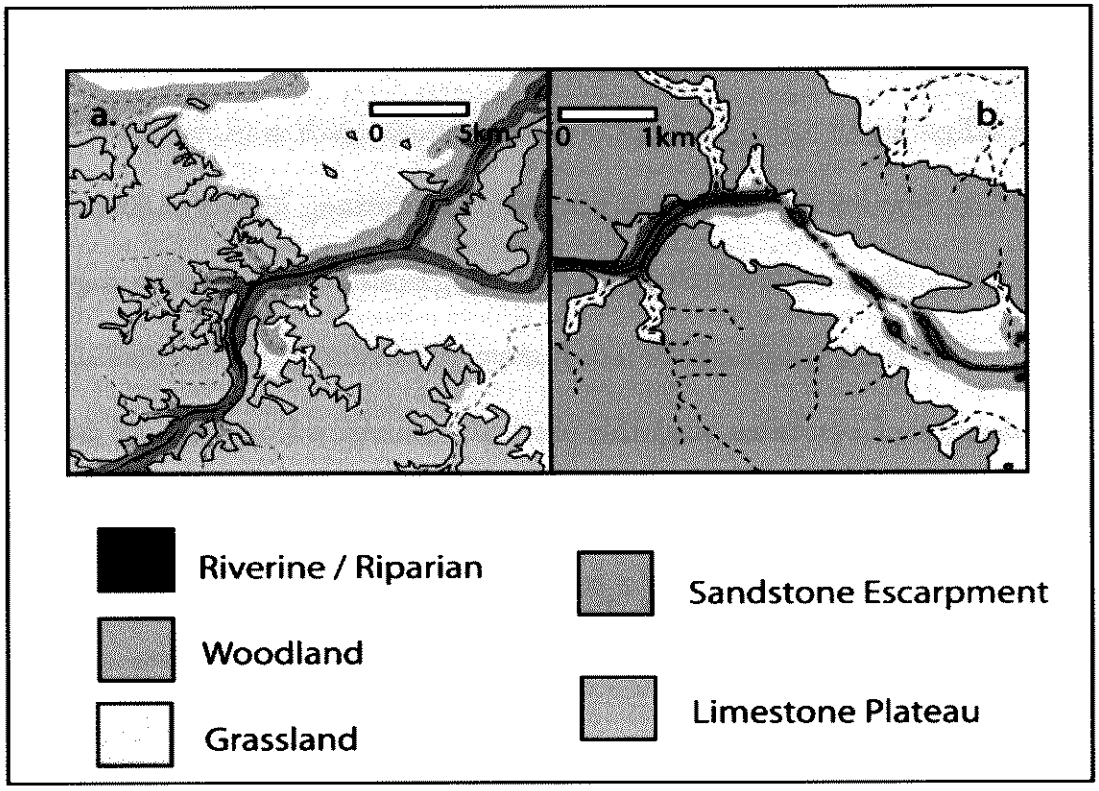

Figure 5.8: Diagram of ecosystems of Riversleigh (a.) and Musselbrook (b.) showing the extent of each of the local patches. Note that limestone plateau does not occur at Musselbrook and that orange shading indicates sandstone escarpment areas.

5.4 Settlement and subsistence at Riversleigh / Lawn Hill through time

This section describes a model of subsistence and settlement for the study region. It combines the models of expected forager behaviour stemming from Human Behavioural Ecology, the data concerning local resource availability (modern patches and diet breadth) and how considers these might change through time. This model provides a series of expectations in foraging behaviour that will be tested against the archaeological data presented in the next two chapters.

The settlement and subsistence model for Riversleigh/Lawn Hill is based on the current best knowledge concerning climate changes over the last 50,000 years. It consists of six

broad periods: 1. Colonisation phase (50,000 to 30,000 BP), 2. the Last Glacial phase (30,000 to 18,000 BP), 3. Pleistocene recovery phase (18,000 to 10,000 BP), 4. Holocene wet phase (10,000 to 5,500 BP), 5. short arid phase (5,500 to 2,000 BP) and 6. the recent phase (2,000 BP to c. 50 BP).

The model relies upon the assumption that hunter-gatherers sought to minimize uncertainty whilst maximizing returns in pursuit of resources. Forager settlement patterns assume a range of predictable patch types and geographic dispersal with a good level of predictability. For each patch of the study area predictions can be formulated on the nature and density of resources and the predicted nature of occupation and dominant foraging pattern through time.

5.4.1 Diet Breadth Model through Time

It is important to gauge how patch choice and diet breadth models for Riversleigh/Lawn Hill might have changed through time, particularly in reference to environmental changes brought about by climatic variability for each of the above phases. As there is no accurate data concerning faunal spatial variability through time upon which to base such an analysis it has been necessary to develop a model of expected changes in the range of different species through time. This model is presented below in Table 5.6.

Table 5.6 illustrates the relationship between resources as expressed as a diet breadth table, by reference to patch types (*i.e.* riverine/riparian, woodland, grassland and limestone plateau), and to the large-scale climatic changes. High ranking resources, including plant products and animals, were reduced in abundance and density in most patches during periods of aridity. Lesser ranked riverine resources might have remained fairly constant. During periods of increased aridity resources such as honey and fruit would have decreased in availability as woodlands and riparian patches became depleted and reduced in size.

Similarly, other highly ranked resources like eggs would have become far more scarce due to reductions in birthing rates due to stress and increased competition.

The model also predicts large changes in the structure of large and medium mammal and reptile populations. At present high to medium frequencies of animals like kangaroos can be found in woodlands and riverine/riparian areas (usually at watering times). During periods of increased aridity (periods B and E) these animal populating numbers would be expected to show a shift in abundance from high to low as well as becoming more dispersed or clumped. The relative abundance of kangaroos might decrease during the LGM (period B) though it might only reflect clumping around more permanent water. Increased resource clumping might actually make for better rates of resource acquisition, despite the lower abundance. It also follows that clumping of lower ranked resources like mussels in deep slow moving pools of water is significant, rather than their location within a particular stretch of river.

Whilst the effects of periods of greater aridity are likely to have had great impacts on resources with a high ranking in the diet breadth model, the same is not expected for those resources lower on the table. Medium mammals, fish and medium birds are thought to have remained relatively static (although effected by reductions in patch extents) whilst lower ranked resources such as mussels, tubers and seeds are thought to have changed very little through time.

Resource	Phase A 50,000 - 30,000BP				Phase B 30,000 - 18,000BP				Phase C 18,000 - 10,000BP				Phase D 10,000 - 5,500BP				Phase E 5,500 - 2,000BP				Phase F 2,000 - 0 BP			
	R	W	G	L	R	W	G	L	R	W	G	L	R	W	G	L	R	W	G	L	R	W	G	L
Honey and Lerp	M	M			L	L			M	M			M	M			L	L			M	M		
Edible Fruit	H	H	L		M	M			H	H	L	L	H	H	L	L	M	M			H	H		
Eggs	H	H	L	L	L	L			H	H	M	L	H	H	M	L	L	L	L	L	M	M	L	
Large mammals and reptiles	H	H	L	L	M	L	L	L	M	M	M	L	M	M	M	L	M	L	L	L	M	M	M	L
Medium mammals and reptiles	H	H	L	L	M	L	L	L	H	H	M	L	H	H	M	L	M	L	L	L	H	H	M	L
Large birds	L	M	L		L	L	L		L	M	L		L	M	L		L	L	L		L	M	L	
Large Aquatic Animals	H				M				M				H				M				H			
Fish	H				M				H				H				H				H			
Medium birds	M	H	M	L	L	L			M	H	M	L	M	H	M	L	M	M	L		M	H	M	L
Freshwater Mussels	H				H				H				H				H				H			
Shallow Rooted Non-Toxic Tubers	H	H	L		M	L			H	H	L		H	H	L		M	L			H	H	L	
Arboreal Animals	H	M			M	L			H	M			H	M			M	L			H	M		
Tree Seeds	M	H	L	L	M	M			M	H	M	L	H	H	M	L	M	M	M		M	H	M	L
Grass Seeds (*Poacae*)			H	H			H	H			H	H			H	H			H	H			H	H

Table 5.7: Diet breadth model for Riversleigh and Lawn Hill, northwest Queensland expressed for each of the analytical phases examined archaeologically and based on source material, observed abundance in research area, and expected ease of capture. Patches are shown across the top of the table R=riverine/riparian, W=woodlands, G=grasslands, L=limestone plateau. Abundance of resource is indicated by H=high, M=medium, L=low.

5.4.1 Phase 1 – Colonisation (50,000 to 30,000 BP)

The colonisation period is when the first hunter-gatherer groups entered the study region. The timing of first settlement of the region is argued to have been contemporary with first settlement of Australia. If colonisation of Australia occurred prior to 50,000 BP then we might expect an initial colonisation date from the study region close to this time. If however, the shorter chronology is the better reflection of the antiquity of Aboriginal settlement then we might expect an arrival date in the study region of closer to 40,000 BP.

Humans traversing the study area probably followed permanent watercourses like the Gregory River from the southern area of Lake Carpentaria after colonisation through present day New Guinea. A second, less likely route into the study region is from the west. People may have arrived in the study area after entering Australia from Timor into the Kimberley region, or through Arnhem Land, crossing the arid zone and subsequently the study region, but this is considered less likely. Evidence for the most likely route will come from the location of sites from this initial period and material culture that may or may not be associated with desert adaptations.

If humans arrived in the study region sometime prior to 30,000 BP, they would have faced a landscape possibly colder, but wetter than today. Resource patches would have mirrored the patches discussed above: riverine and riparian, woodland, grassland and limestone plateau.

The first population of the study area is expected to have been small. The preferred migration route from Lake Carpentaria would imply that this population had a high level of residential mobility, as they sampled the landscape along their route. This might have involved seasonal visitation to the study area initially from residential bases at the south of the lake. Foraging behaviour is predicted to have reflected a broad based economy using a combination of patches as almost an exploratory system, testing patches and resources and

developing logistically sustainable diet breadth. Over this 10,000 year phase the spread and location of sites would have become more focused on the most productive patches. It also holds that during this phase there would be variability in flaked stone artefact reduction strategies, use of a wide range of raw materials and a tendency for low diversity in individual provisioning. It is also expected that there might be seasonality in mobility levels and in the types of resources that were exploited, as during dry seasons there would have been higher subsistence risk.

5.4.2 Phase 2 – Oxygen Isotope Stage 2 and the Last Glacial Maximum (30,000 to 18,000 BP)

OIS2 represents a significant change to the climate in northern Australia and particularly for the study region. During this phase, and particularly during the peak in aridity between 20,000 and 18,000 BP, water was restricted to those areas that are today permanent and substantial rivers. Phase 2 occupation will reflect one of the arid models (as per chapter 2) and was either continual, fluctuating or the region was abandoned. If the region was abandoned then any archaeological sites are expected to display evidence of a hiatus in their occupation sequences as reflected in discard of cultural material.

The alternative to abandonment involves a variety of options: *(i)* people inhabited the gorges of permanent watercourses continually; *(ii)* there was frequent visitation by a few people; or *(iii)* visitation consisted of longer range trips (perhaps made seasonally) by foragers from downstream Lake Carpentaria. Evidence of each scenario could consist of cultural material that is reliably dated to this period, the absence of hiatus features in cultural sequences, and in the nature of the assemblages (*i.e.* the presence of exotic materials). If people continued to inhabit the region or visited regularly then we would expect that the population was subject to high levels of resource risk at any distance from riparian/riverine patches as resources and other patches became depleted.

Increased uncertainty in foraging success would have had extensive and observable effects on behaviour. There might also be accompanying significant changes in group territoriality and a reduction in residential mobility. This might be observed in increases in the intensity of cave occupation near to permanent rivers. It is also expected that resource depletion and increased patchiness would lead to increased diet breadth to balance increased risk through lower encounter rates of prey. Under pressure, foragers would be expected to increase their diet breadth to include lesser ranked prey items that are argued to have been more readily available than those of higher value. An alternative or complement to this argument is that foragers may also have acted to improve their level of foraging success by specialization in certain resources, for example riverine foods, such as mussels.

During this extreme period, it is hypothesized that there will be accompanying changes in lithic technology including an increase in the extent of reduction. These changes will be observable in the frequency of cores and small flakes present in archaeological sites. Debitage might also display characteristics consistent with greater control and precision in knapping so as to minimize waste (as argued by Hiscock 1988). It would also be expected that only local raw materials would be exploited at this time. As the Riversleigh and Lawn Hill parts of the study region have a different configurations of water availability and location of good knappable lithic raw material, these technological traits may be different in the two areas. At Riversleigh it is predicted that the lithic assemblage displays characteristics of general expediency in stone tool design and use as part of a broader strategy of resource use, whilst at Lawn Hill there might be evidence of greater curation. In both areas it is expected that any changes to reduction strategies would reflect technological solutions appropriate to specific needs.

5.4.3 Phase 3 and 4 – Recovery Phase (18,000 to 5,500 BP)

Between 18,000 and 5,500 BP the climate of northern Australia recovered significantly from the preceding glacial phases to a level where rainfall and average temperatures were greater than today. During this phase there was improving resource abundance, stability in rainfall and temperature and a more homogenous distribution of resources. It is hypothesized that a third major reconfiguration in forager use of the landscape occurred during this time. Foragers were now presented with opportunities associated with far lower levels of risk associated with resource acquisition and enhanced vegetation and faunal availability.

During this phase higher levels of patch productivity would have allowed foragers to expand residential settlement locations, and exploitation of greater areas of patches and more marginal areas such as the grasslands. Residential expansion to the other lesser riverine patches along smaller permanent and semi-permanent water courses such as Mussellbrook Creek would also be evident.

Given these circumstances it is likely that a resident population would be able to increase in size due to higher patch productivity. It is likely that whilst settlement locations grew they were aggregated around large standing bodies of water, within gorges and on the eastern plains, with associated low residential mobility. It is expected that sites that were residences would be present along watercourses and that associated assemblages would be of increased size and density compared to other periods.

Current paleoclimatic data indicates a small peak of aridity at 10,800 BP (The Younger Dryas). This might have resulted in a short-term period of higher foraging uncertainty, with possible impacts on population levels and mobility. The archaeological signature for this particular time might be reflected abrupt changes discard rates and raw material transport but given the short duration might be difficult to detect archaeologically.

Towards the end of phase 4 (between approximately 8,000 to 5,500 BP) we would expect that the study region was supporting larger populations who were able to live far more sedentary lives with fewer constraints on subsistence and technology. Archaeological evidence of this pattern should be reflected in larger and more complex residential base sites and greater complexity in temporary camps. Greater artefact reduction and an increase in debitage in sites and in the percentage of debitage with little or no cortex should feature.

5.4.4 Phase 5 – El Nino Aridity (5,500 to 1,500 BP)

During this phase climate deteriorated significantly, with a peak in the severity of arid conditions considered to have occurred between 3,500 and 2,000 BP. ENSO driven aridity would have increased foraging uncertainty through changes in vegetation range and density leading to increased patchiness. Under these conditions foragers are expected to have adapted to a subsistence strategy featuring higher mobility once again. It is also possible that population declined at this time due to changes in resource availability.

Changes in foraging strategies that were aimed to reduce foraging risk are expected to be reflected in changes in toolkit design and the general organization of technology. Possible changes might include the introduction of new technology, higher levels of tool diversity, evidence of individual provisioning and greater reliance on maintainable and reliable technologies. Technological innovations aimed at reliability might include redundant elements, and easily replaceable parts such as spear barbs or points (see Bleed 1986).

5.4.5 Phase 6 – Recent (1,500 to 50 BP)

Over the last 1,500 years the Australian climate has improved significantly from the phase 5 El Nino period. It is expected that during this time the Aboriginal population of the study area increased significantly and that residential settlement locations expanded as an effect of this, to a level that encompassed most rivers and with them most patches of the

study region became well utilised. With reduced subsistence challenges foragers would have had predictable provisioning strategies shifting from their previous strategies that sought to minimise foraging uncertainty.

The archaeological signature of the last 1,500 years is therefore expected to consist of a high frequency of residential base sites (this is also due to taphonomic reasons, that is higher visibility), in all riverine/riparian and woodland patches. It is also expected that temporary camps would occur in greater numbers along lesser permanent water courses and semi permanent creeks, representing a combination of both logistical and residential mobility and seasonality in landscape use. Technological diversity is expected to be highest during this phase as a result of hereditary lineages in artefact manufacture and by the nature of increased sample size.

5.5 Conclusion

A model of settlement and subsistence for the study region based on the framework of Human Behavioural Ecology (HBE) and evolutionary anthropology has been presented. This model for the study area is based on a composite of the Patch Choice and the Diet Breadth Models and expected foraging strategies, and has been developed based on other regional correlates (see Barton 2001; Clarkson 2004), an understanding of landscape units (in terms of geology, topography, hydrology), known patch types, faunal survey and contemporary Aboriginal resource use and knowledge.

The Riversleigh/Lawn Hill settlement and subsistence model has outlined specific expectations regarding forager behaviour within the study area landscape and related these to climatic changes which have occurred over the last 50,000 years. With this established, the following chapters present the results of archaeological investigations at Riversleigh/Lawn Hill, the data of which will be used to test the current model.

Chapter 6

Survey and Excavation in the Southern Study Area - Riversleigh

6.1 Introduction

The next two chapters report on the results of excavation of archaeological sites spread across the study area. Open sites and rockshelters were investigated, focusing on the different river systems and on different local resource patches.

Chapter 6 presents results of excavations and survey in the Riversleigh area of the research region. Riversleigh provided the main focus of research between 2002 and 2004, and where five archaeological sites were excavated. These consisted of open scatters, middens and rockshelters at varying distances from permanent water. The results of the excavation program at Riversleigh are compared and contrasted with the results of Hiscock's' study at Lawn Hill to develop an overview of the region.

6.2 Surveys

The Riversleigh fieldwork had two aims: *(i)* to undertake detailed archaeological excavation of sites discovered along the Gregory River.

Investigations at Riversleigh consisted of survey along the course of the Gregory River from approximately 3 km on the eastern plain to a distance of approximately 10 km west of the commencement of limestone gorges. Other areas in the region also surveyed, including an ephemeral tributary of the Gregory River called Verdon Creek, and the lower

reaches of the O'Shannassy River., and other areas where rock art had previously been recorded (Figure 6.1).

Surveys identified rockshelter and cave sites and areas that featured rock art. Documentation of sites involved detailed photographic recording, probing of sediments in shelters to determine the depth of deposit and potential for subsurface investigations, and completion of QPWS site forms. Thirty three archaeological sites were recorded during the survey, some of which already known.

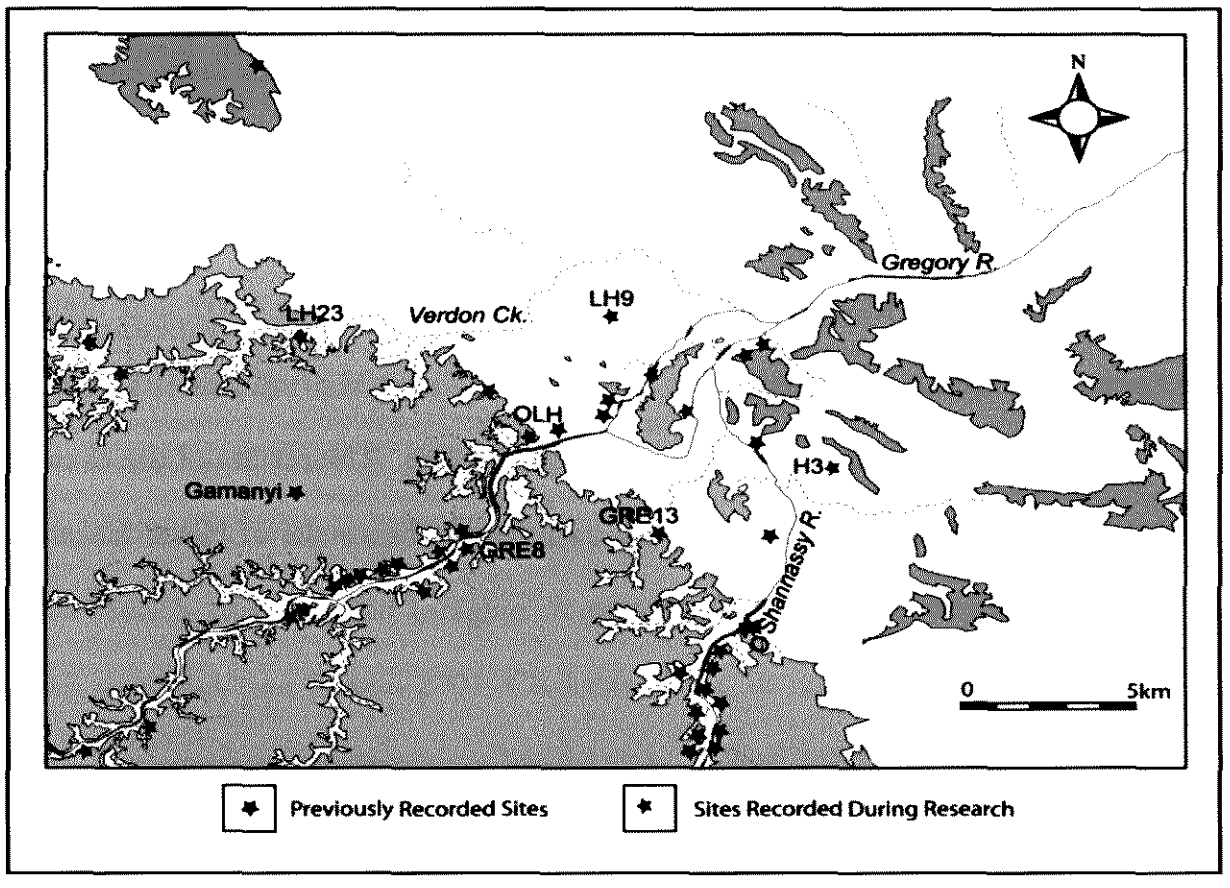

Figure 6.1: Riversleigh, northwest Queensland showing the location of sites recorded during survey for this project. Sites that have been excavated are labeled by name.

The initial survey identified the number of rockshelters that have potential cultural accumulations and were in close proximity to the Gregory River. Although the limestone geology of the Gregory River has led to the creation of extensive cave systems, very few of

these were of sufficient size and accessibility to have afforded shelter. Where caves of suitable size for occupation were found, most were in locations that were subjected to scouring during the high water-flow of the wet seasons. Consequently very few rockshelters featured sediment accumulation greater than a few centimetres, and as such were unsuitable for excavation. However, four sites did have potential for excavation: two rockshelters on the Gregory River, one on Verdon Creek and one at the junction of the Gregory and O'Shannassy Rivers. Of these sites only the Verdon Creek shelter (site LH23) and the GRE8 site located along the Gregory River were excavated.

Continuing and inclusive consultation with the Waanyi community resulted in visits to known sites of cultural importance. These sites included large shelters and cave complexes that occur over 2 km from permanent water and within different geological and environmental units to the previously targeted locations. Two sites were identified with potential for archaeological investigation: *(i)* the 'Grotto' (GRE13) and *(ii)* 'Gamanyi' (Carrington's Cave).

In total, five sites were excavated in the Riversleigh section of the study region - the open sites O'Shannassy Hearths (H3), and Old Lilydale Midden (OLH), plus the rockshelter and cave sites GRE8, Gamanyi and GRE13 rockshelters.

6.3 Riversleigh - Sites close to permanent water

6.3.1 O'Shannassy Hearths

The O'Shannassy Hearths are located on an erosional Holocene floodplain adjacent to an unnamed ephemeral tributary, east of the O'Shannassy River. The site consists of a complex of hearths, artefact scatters, isolated finds and a burial in an area of approximately 800 m x 300 m. Approximately 60 hearths have been recorded, and over 20 artefact scatters at these locations. Twelve ground stone axes manufactured from non-local raw

material were recorded. Most of the hearths are likely to be contemporaneous, given similar stages of weathering and the presence of relatively well preserved charcoal.

Site Setting

The O'Shannassy Hearths are located in the grasslands patch type where there is low vegetation cover over the site area. A thin band of woodland occurs between the site and sandstone escarpment and is associated with an ephemeral stream of the O'Shannassy River. Approximately 500 m west of the site there are a number of seasonal channels of the river that feature sparse, medium density woodlands. During most of the year permanent water is only available from the O'Shannassy River c. 750 m west of the site.

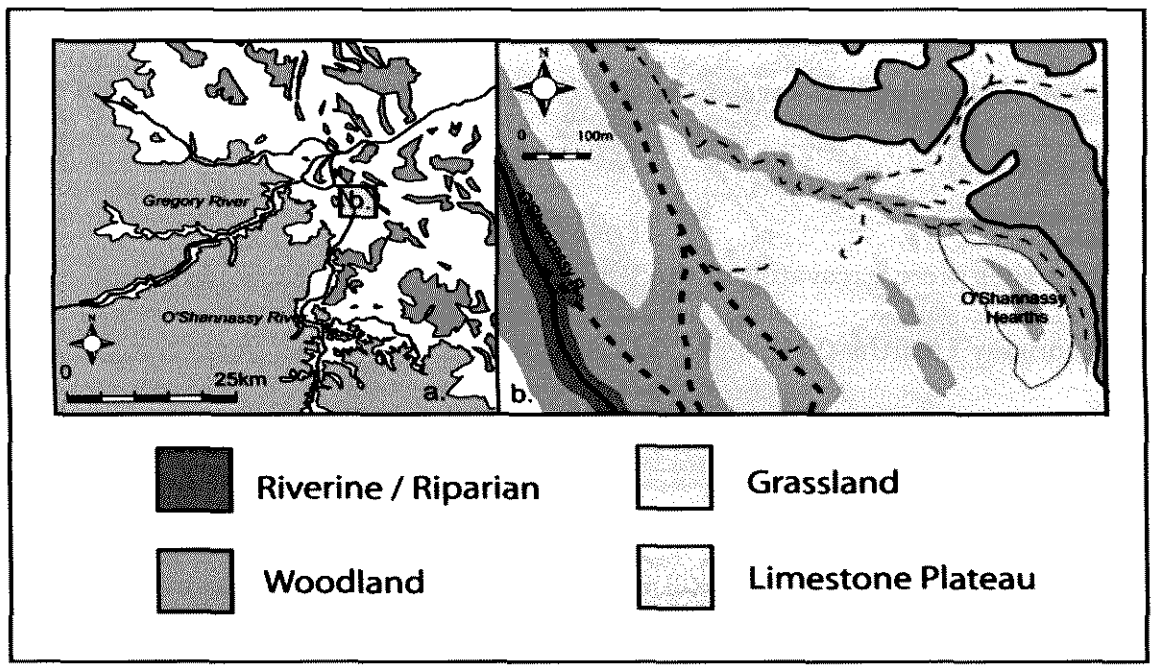

Figure 6.2: Location of the O'Shannassy Hearths site, Riversleigh northwest Queensland. A. shows the general location of the area marked as B. B details the relationship of the hearths to patch types.

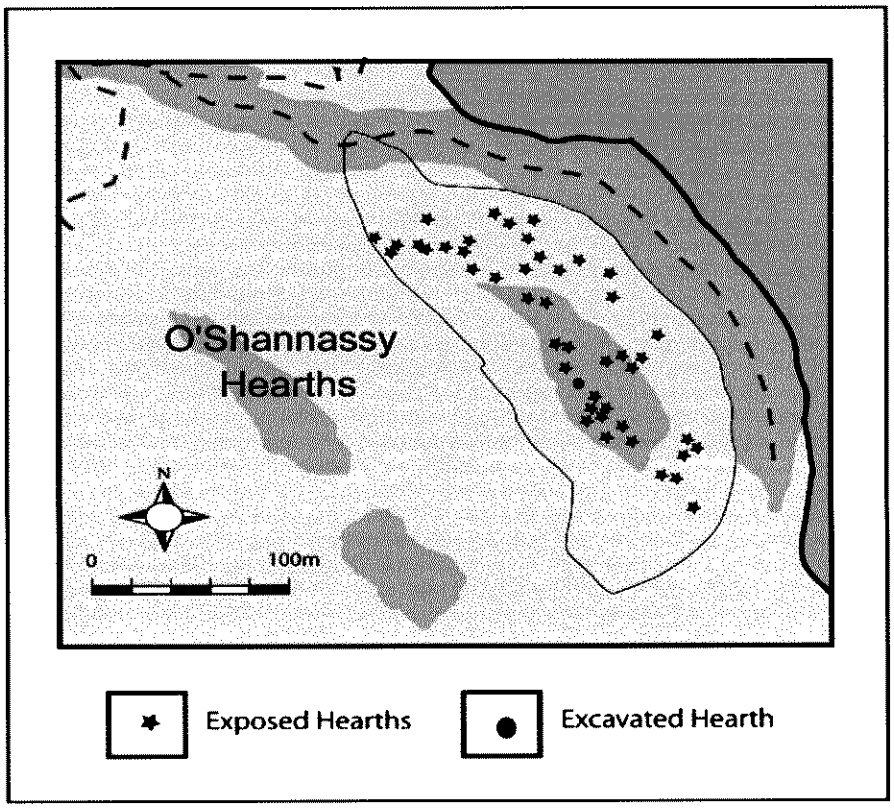

Figure 6.3: O'Shannassy Hearths site, Riversleigh, northwest Queensland. Showing location of exposed hearths and the excavated H3.

Description and Dating

One of the hearths from the O'Shannassy Hearth site was excavated to investigate structure, content, age, and the associations with the transported axes. The H3 location consisted of a large intact hearth feature measuring approximately 40 cm x 50 cm comprising a mixture of loosely packed sandstone, and charcoal. Excavation of the H3 feature was limited to the eastern half of the feature, and undertaken in 5 cm excavation to approximately 20 cm below the surface. Charcoal from the hearth returned a radiocarbon determination of 375 ± 40 BP indicating the site may have been used until close to European settlement. Another interesting aspect of this site is the prevalence of sandstone grinding stone fragments within the oven feature. It appears that several may have originated from larger sandstone grinding dishes, many of which litter the O'Shannassy Hearth site.

Figure 6.4: Profile of the H3 feature showing location of C14 sample

Summary

The total assemblage at the O'Shannassy Hearths includes flaked stone artefacts, large numbers of locally obtained grindstones and many non-local edge ground axes. The O'Shannassy Hearths site and are indicative of people with a broad resource base probably including grass seed processing and perhaps also including extensive trade networks. As the tributary adjacent to the O'Shannassy Hearth site is an ephemeral stream, it is likely that the site represents the remains of a residential base which was occupied during the wet season when local resources were abundant enough to support large numbers of people.

6.3.2 Old Lilydale Homestead Midden

Site Setting

The Old Lilydale Homestead Midden (OLH) is located 150 m from the north bank of the Gregory River on the eastern portion of the study area, and 500 m from the commencement of the local limestone plateau (Figure 6.5). The site is in close proximity to the historical ruins of the Old Lilydale Homestead, a pastoral station which was

occupied by European settlers in the late 19th century. Underlying the historical ruins and extending for over 500 m further east and west, is a prehistoric Aboriginal shell midden complex.

Adjacent to the OLH site, the Gregory River forms a slow moving body of water, over 5m deep and approximately 50 m wide. A shallow, tufa dam located 1 km downstream provides an abundance of riverine resources and acts as a crossing point. The midden itself is approximately 5 - 8 m above the wet season level of the Gregory River and as such is not subject to any seasonal flooding. At this location extensive erosional features (gullying) have been created by erosion caused by stock with channels also developing from rainfall runoff.

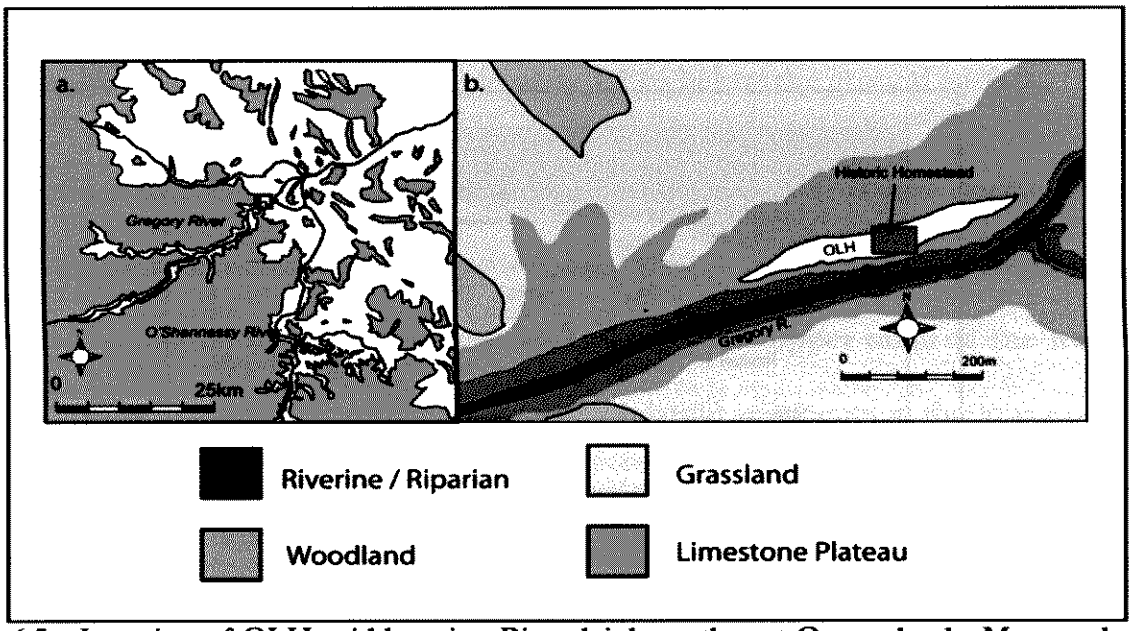

Figure 6.5: Location of OLH midden site, Riversleigh northwest Queensland. Map a. shows the regional setting of OLH. Map b. shows the location of midden site, the relationship to local patch types, and the historical site

The OLH midden is situated in a woodland patch within 50 m of riparian vegetation. The vegetation is dominated by eucalypts with an under storey of scattered shrubs and grasses. A band of what is best described as grasslands occurs only 200 m north of the site, extending only a few hundred metres before terminating in Cambrian limestone outliers

associated with the plateau feature. These grasslands are considered a relatively modern patch created by the erosion due to historical pastoral activities.

Site Description

The OLH midden consists of an expansive shell exposure, visible in section in the erosion gullies, and as a deflated surface scatter of highly fragmented shell caused by trampling by cattle. The extent of the visible scatter is approximately 500 m x 300 m. During 2002 fieldwork, the location of the site was mapped using EDM survey and in 2003 the central area of the midden was recorded using differential GPS, which plotted the location of exposed shell and the erosion gullies (Figure 6.6). Whilst conducting this survey details concerning the depth, density and composition of the midden exposures were recorded. Four samples of midden material were obtained and one area was selected for excavation.

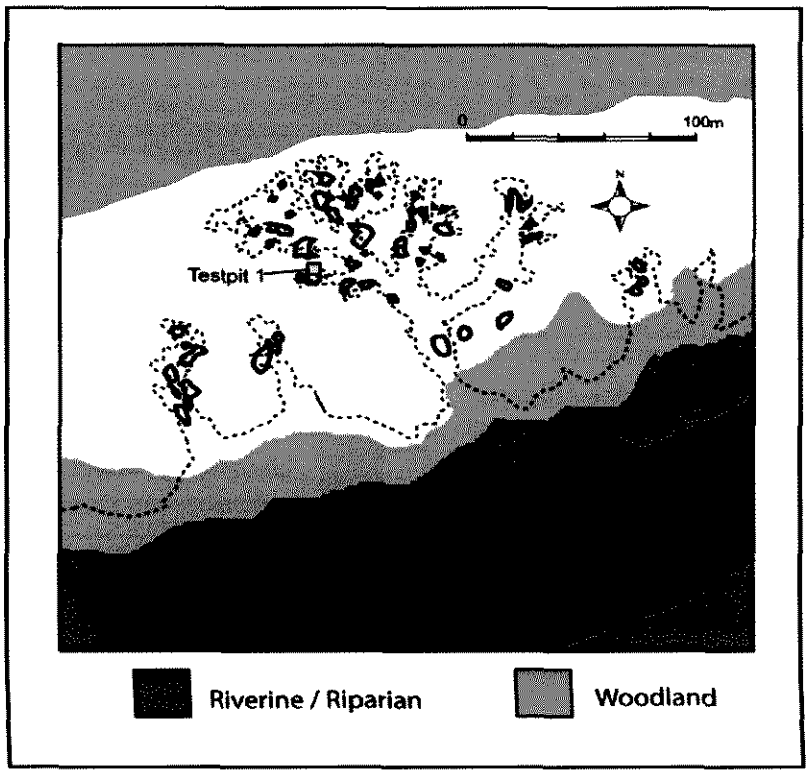

Figure 6.6: OLH midden site at Riversleigh, northwest Queensland. Map indicates the location of excavated square Testpit 1, the extent of erosion gullies as dotted lines, and areas of high density midden accumulation as red polygons.

Excavation

Investigation of the OLH midden involved preparation of a section profile in an erosion gully to gauge the depth and stratigraphy of the midden, followed by excavation. The section profile revealed that adjacent to this location that the depth of the shell deposit was c. 1.1 m.

OLH Test Pit 1 (TP1) was located on a narrow spur created by gully erosion of the OLH site. Excavation involved removal of surface vegetation of light grass cover and surface finds followed by excavation in 5 cm spits within stratigraphic units to a depth of approximately 90 cm below surface. At this point archaeologically sterile sediments were encountered. Below this point a further 50 cm x 50 cm square in the northwestern corner was continued for another 20 cm. A total of 20 spits were removed in the OLH TP1 trench terminating at a depth of approximately 1.1 m below the ground surface.

Stone artefacts and complete shell valves were recovered and bagged during excavation. All other excavated material was sieved on site using 4 mm and 2 mm mesh and some preliminary sorting of the finds was also completed. The upper units of the trench were dry sieved (spits 1 - 9), however due to the consolidating sediments in the lower units (spits 9 - 20) these units were wet sieved in the Gregory River. All material that was wet sieved was dried prior to being placed in plastic bags. At the completion of test excavations the OLH TP1 trench was backfilled.

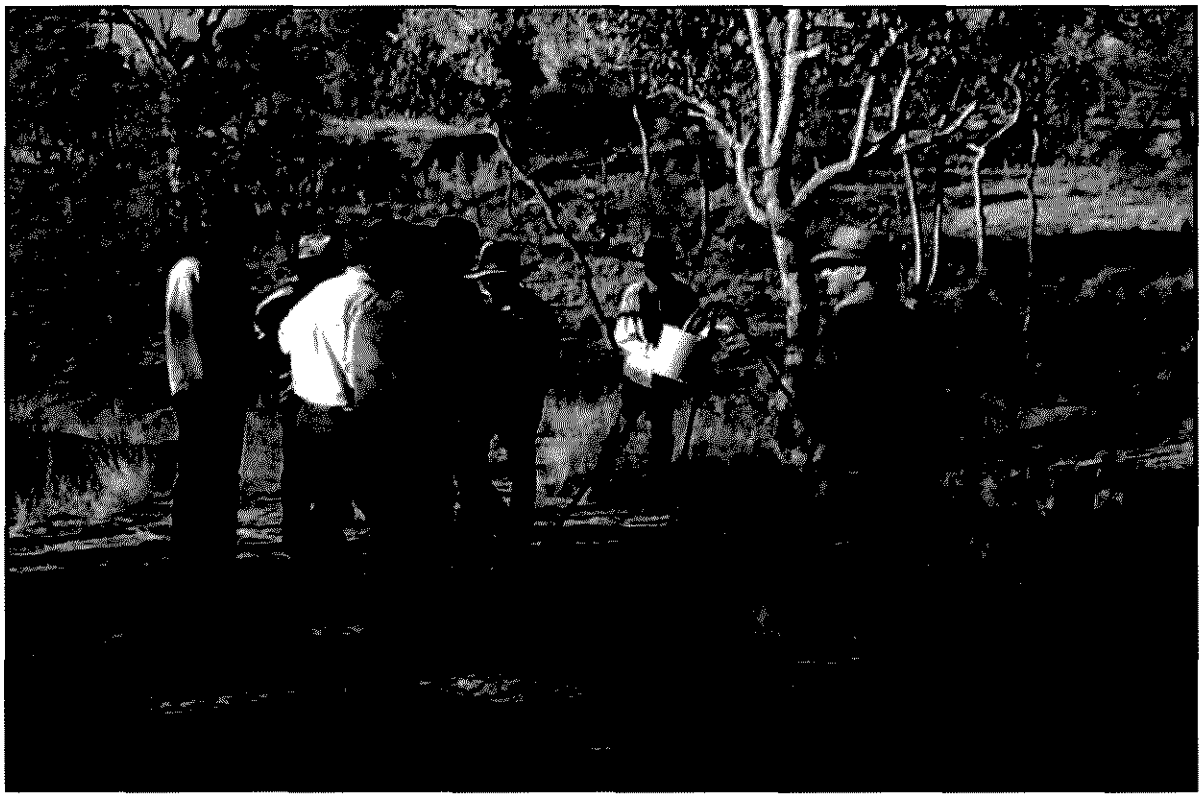

Figure 6.7: The OLH TP1 excavation. Members of the Waanyi community were present and were actively involved in excavation, sieving and sorting of finds. Richard Fullagar and Andrew Border are in the foreground.

Stratigraphy

Three primary stratigraphic units were identified in OLH TP1. Unit 1 (25 cm - 0 cm depth) consists of yellow-brown sandy sediment containing a low concentration of shell and a few stone artefacts. Unit 2 (75 cm - 25 cm depth) consists of a dense accumulation of freshwater mussel shells of the species *Alathyria pertexta spp.* and an increased concentration of stone artefacts. Unit 3 (110 cm - 76 cm) consists of a layer of sterile sandy sediment with stone artefacts recorded in association with shell only in the upper 10 cm of this unit.

Subsequent analysis of material from OLH TP1 revealed that the stratigraphy of the site to be more complex than first noted in the field. Five distinct stratigraphic layers of shell were identified by extrapolation of shell weights and NISP counts recorded for each cubic

metre of sediment. Subsequent examination of stratigraphic drawings, excavation records, and photographs support a division of the stratigraphy into eleven depositional units (Figure 6.1, Table 6.1).

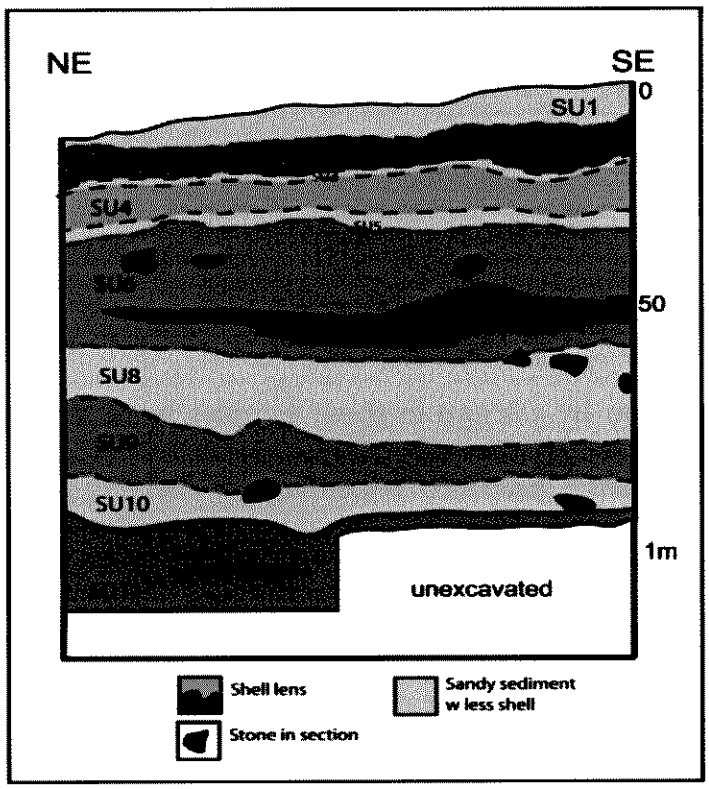

Figure 6.8: Section profile of OLH TP1, Old Lilydale Midden, Riversleigh, northwest Queensland

Stratigraphic Unit	Depth below surface	Unit type
1	0 – 7 cm	Sandy soil
2	7 - 15 cm	Shell lens
3	15 - 16 cm	Sandy soil
4	15 - 27 cm	Shell lens
5	27 - 30 cm	Sandy soil
6	30 - 46 cm	Shell lens
7	46 - 52 cm	Shell lens
8	52 - 55 cm	Shell lens
9	55 - 76 cm	Shell lens
10	76 – 88 cm	Sterile unit
11	88 – 110 cm	Sterile unit

Table 6.1: Depositional history of OLH TP1 site based on post fieldwork analysis

Chronology – C14 determinations

During excavation of the OLH TP1 site very little charcoal material was observed or recovered. Preliminary sorting of material post fieldwork recovered 'charcoal-like' material, however it was not considered reliable to submit this material for radiocarbon dating due to the small sample sizes and a lack of stratigraphic resolution beyond 5 cm spit depths. Three samples of freshwater mussel shell (*Alathyria pertexta spp.*) that had been collected *in situ* were submitted for C14 analysis.

The complexities relating to the radiocarbon dating of freshwater mussel shell and the potential for contamination by calcium in these samples were recognized at the time. As such, the three samples were prepared according to detailed procedures established in consultation with ANSTO, the late Mr. J. Head (UOW) and Professor L. Field (USyd). These procedures included surface etching and cleaning of post depositional calcite from shell valves using a dental drill. Aragonite samples were obtained and sealed in nitrogen environments prior to submission. Small samples of this material were also separated and tested for possible re-crystallization using Fulimer transfer infra-red spectroscopy. No evidence of re-crystallization was noted.

Table 6.2 details the results of the radiocarbon determinations (Waikato University). The radiocarbon determinations have been calibrated using Calib Radiocarbon calibration program and expressed to two standard deviations. All three radiocarbon determinations overlap at 2-sigma, indicating that the site was formed between 14,416 and 16,175 Cal. BP. A correction of 2,500 years (Drysdale and Head 1994, 1998; R. Drysdale pers. comm.) based on dates obtained on living shells was applied for a local Gregory River reservoir affect. The age range for the OLH TP1 deposit falls between 11,916 and 13,765 Cal BP.

id	lab id	material	Raw date	error	calib lower	calib upper	less reservoir effect	
OLH Tp1 Sp2 (10cm)	Wk-12226	shell	13061	81	14621	16122	12121	13621
OLH Tp1 Sp10 (50cm)	Wk-12227	shell	12886	83	14416	15879	11916	13379
OLH Tp1 Sp20 (100cm)	Wk-11430	shell	13092	85	14670	16175	12170	13675

Table 6.2: Radiocarbon determinations for shell samples from the OLH TP1 midden site showing uncalibrated, calibrated and reservoir corrected calibrated ages for the deposit expressed at 2-sigma.

Site Formation and division of deposit for analysis

Whilst it is difficult to assess sedimentation rates for the deposit, the site formed/accumulated as people discarded artefacts and the remains of meals. There is no evidence of disturbance in the form of erosion, scouring, or slumping of sediments within the deposit. The sedimentary matrix consists broadly of small rubble and sand with large quantities of shell. This composition does not change in size or consistency with depth within upper sediments. It is only in Unit 1 where particle size decreases due to the dominance of sterile sandy sediments. The radiocarbon determinations indicate that OLH TP1 sediments were the result of rapid accumulation over a period of perhaps just a few hundred years.

Flaked stone artefacts

Distribution

Three hundred and twenty nine flaked stone artefacts were recovered and analysed from the OLH TP1 excavation and include 10 retouched flakes (3.03% of the assemblage), 17 cores (5.16% of the assemblage) and a minimum number of flakes (MNF) of 302 (91.79% of the assemblage). Flaked stone artefacts show greatest concentration in spit 10 (155 artefacts 34.52% of the assemblage), with lesser, but significant, peaks in spits 11 and 12. The retouched artefacts recorded also mirror this relationship, only occurring in spits 10 and 11.

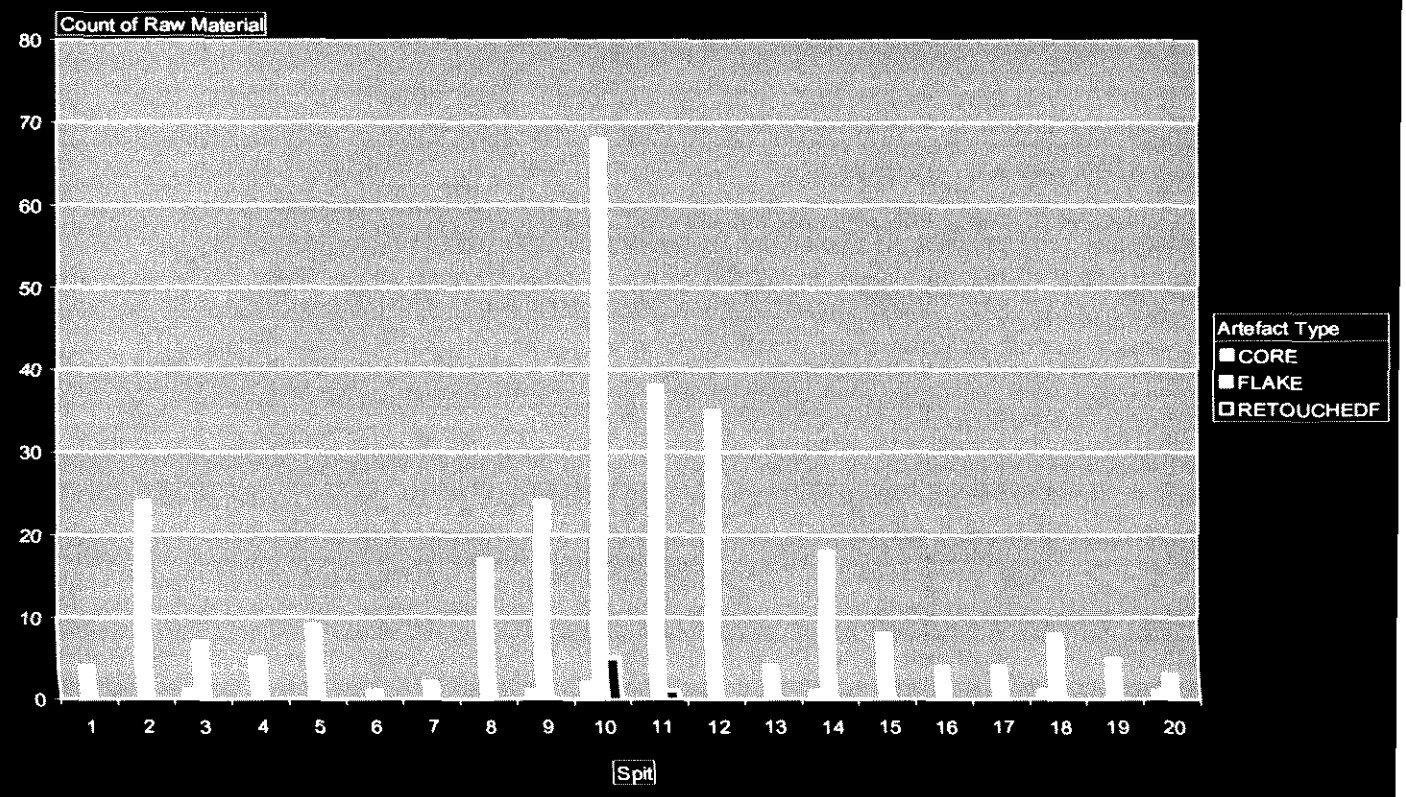

Figure 6.9: Frequency of flaked stone artefacts by excavation unit in OLH TP1, Riversleigh, northwest Queensland.

Stone Raw Materials

Five stone raw materials occur within the flaked stone assemblage in OLH TP1: chert, quartzite, limestone, silcrete and greywacke. Chert dominates the assemblage, accounting for 95.4%, with small quantities of flaked stone manufactured from the other local raw materials also occurring (though they comprise less than 2% of the assemblage). Non local greywacke is considered to have most likely been obtained from the quarry (LH9) located 5 km east of the site and accounts for 4.9% (n=21) of flaked stone.

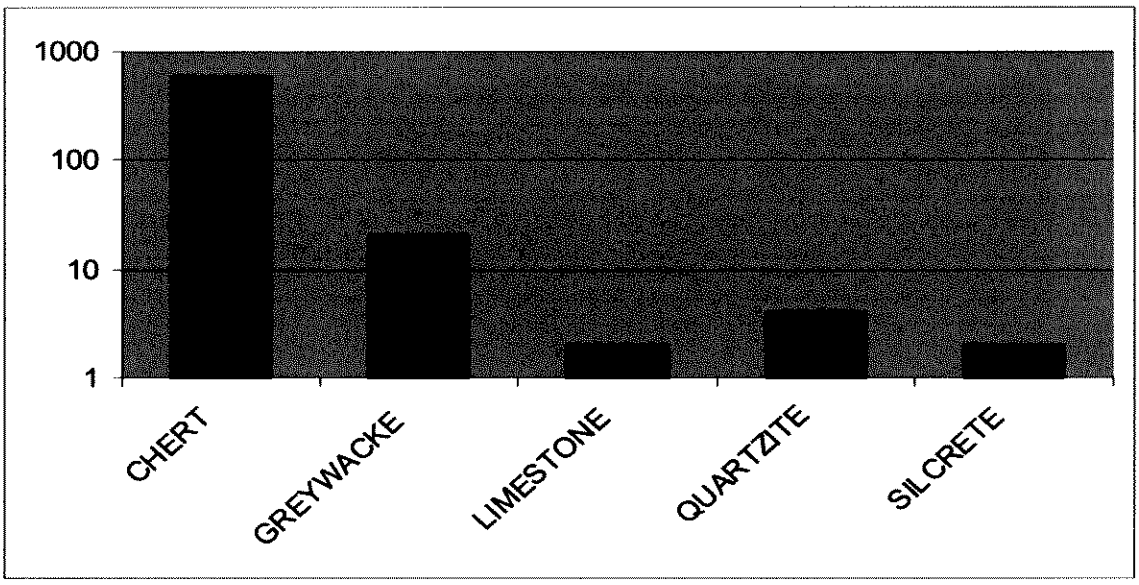

Figure 6.10: Raw Material diversity by number/type in the OLH TP1, Riversleigh, northwest Queensland.

Core Reduction

Nine cores were identified in the assemblage, all being chert. All were much smaller than the average R-chert cobble size indicating discard at a late stage of reduction. The mean block size of the assemblage was 9.23 cm^3 (S.D. = 3.06 cm^3) and mean weight was 14.85 g (S.D. = 7.85 g). Cores were rotated between one and nine times, with the majority of the sample rotated three to seven times. On average over 50% of surfaces had been flaked and an average of 8.66 flakes had been removed from each core. Whilst the mean length of the

longest complete scar was just 17.33 mm (S.D. = 5.82 mm) , all but 2 cores were still usable as indicated by feather terminations.

Flake Reduction

The extent of on site reduction in the OLH TP1 assemblage has been assessed using a simple measure of the amount of cortex present on complete flakes (Figure 6.11). Sixty nine percent (69%) of the flaked stone has less than 25% of dorsal surfaces featuring cortex indicating that the site is dominated by material that is in the late stages of reduction. The chert assemblage is likely to derive from chert river cobbles, which can be obtained a few hundred metres downstream of the OLH site at the tufa dam. The paucity of lithic material in early stages of reduction implies that initial reduction is likely to have occurred elsewhere, probably at the stone source. Only material considered of suitable flaking quality appears to have been taken to the OLH site.

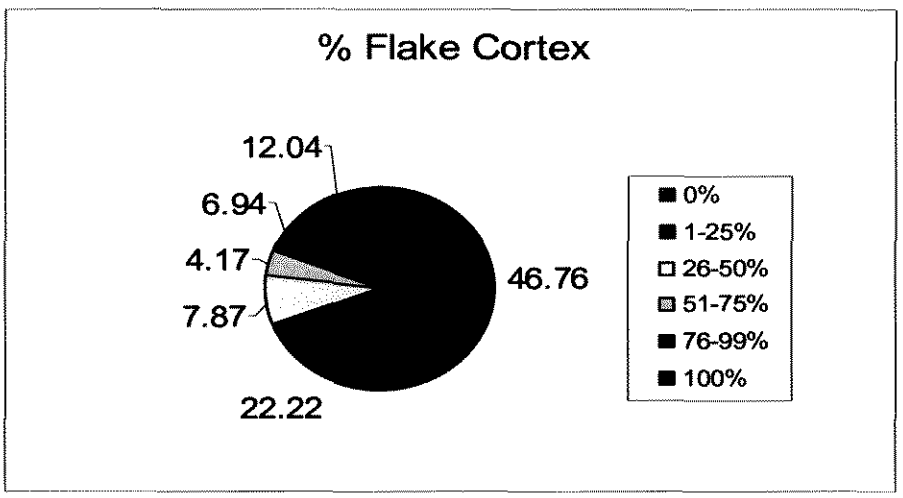

Figure 6.11: Percentage of cortex on all chert flakes from OLH TP1, Riversleigh, northwest Queensland.

Flake Fragmentation

The OLH TP1 assemblage features a small number of broken flakes (n = 62). The vast majority of this breakage is transverse (98.5%) and is dominated by distal flakes (68%). Transverse breaks are most likely to be taphonomic, i.e. through trampling, though breaks do occur during artefact use. Most broken flakes were found in spits 8 - 12 correlating with the largest artefact sample. The high disparity between distal and proximal flakes (Figure 6.12) is probably due to re-use of proximal flakes.

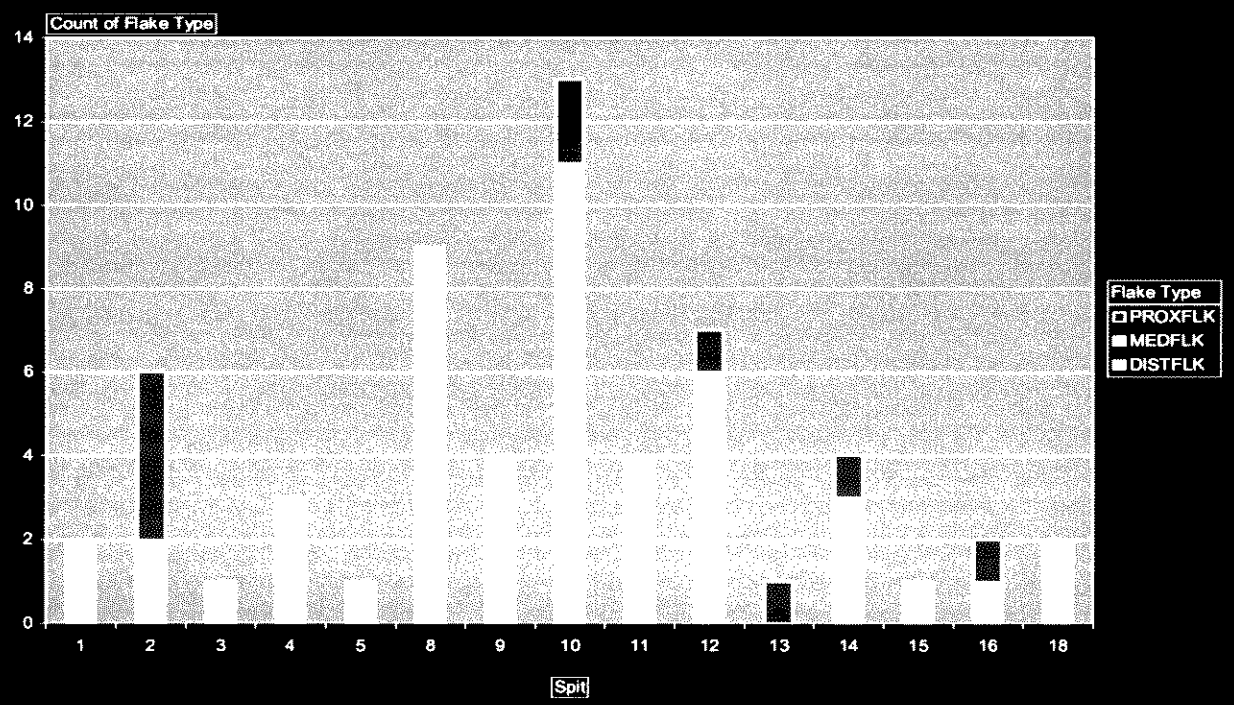

Figure 6.12: Fragmentation of flakes by number and spit at OLH TP1, Riversleigh, northwest Queensland.

Flake Dimensions

Flake dimensions were recorded for all complete flakes in the OLH TP1 assemblage. These measurements consisted of axial length, width and thickness of the flake at mid-point. Additional metrical measurements of the width and thickness of platforms were

also made. Discussion of flake dimensions is restricted to observations concerning chert and greywacke, due to the small sample size of other materials.

In general all chert flakes within the assemblage were small with all but 2 were less than 5 cm in axial length and 48% were found to be less than 2 cm. The width of chert flakes was always less than the axial length, with the average width 15.4 mm. No complete flakes could be classified as blade-like, however 5 broken distal flakes were at least three times longer than wide and most likely originated from large blade flakes. In general the chert assemblage consists of rounded flakes emanating from re-sharpening of implements and the reduction of cores and flakes on site.

Twenty one complete greywacke flakes were recorded from OLH TP1. These flakes were found to be longer but only a few millimetres wider than those produced from chert. The longest greywacke complete flakes were between 45 - 50 mm in length and many broken samples were indicative of possible blades (n=16). No greywacke recorded for the site featured any cortex. These results indicate that only highly reduced greywacke was transported to the OLH site, and that it was most likely used in the production of points and blades (as suggested by Hiscock 1988).

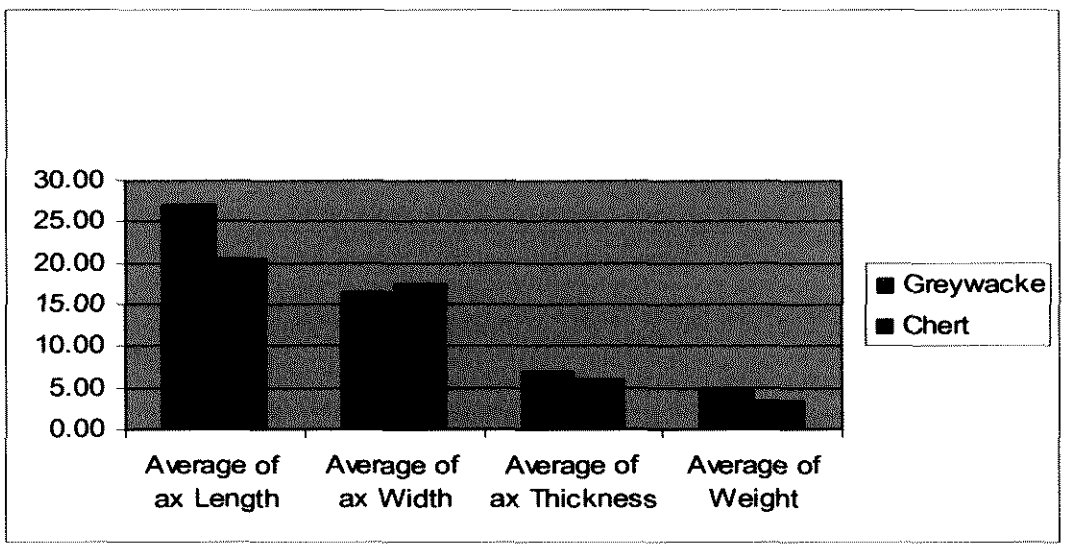

Figure 6.13: Comparison of chert and greywacke flakes (mm) for the OLH TP1 deposit, Riversleigh, northwest Queensland.

Retouched Artefacts

Ten retouched artefacts were recorded from the deposit including two backed artefacts. These artefacts have been examined under low power microscope for evidence of residues and use-wear. Two further retouched artefacts (OLH-TP1-10-002 and OLH-TP1-10-003), chert flakes with intact striking platforms, had been snapped through a distinctive retouched notch. This notching and snapping may be associated with preparation of flake fragments for backing retouch. These artefacts provide additional indication of on-site production of backed artefacts. Additionally, whilst no tulas were recovered, it is interesting to note the prevalence of 16 (4.86% of the assemblage) possible tula pre-forms (large distinctive flakes with pronounced bulbar surfaces and gull-wing shaped wide-area flaked platform surfaces).

Usewear and residue analysis was completed for all retouched artefacts from the OLH TP1 assemblage by Richard Fullagar and Judith Field (see Slack *et al.* 2004). Artefact OLH-TP1-10-001, a chert flake 18 mm in maximum length, 9 mm maximum width, recovered from spit 10, had the platform and termination removed by backing retouch. Steep retouch scars initiated from the ventral surface are continuous whilst steep retouch scars initiated from the dorsal surface are discontinuous, but present at both ends. The chord of OLH-TP1-10-001 had at least one bending scar, and at least 4 scars with feather terminations visible at low magnification (Figure 6.14). At higher magnification (X200) more scars with feather terminations were visible. After sonic cleaning in distilled water for 30 seconds, a distinct film remained visible along most edges. This film was soluble in alcohol and probably comprised lipids, and may be associated with handling during initial analysis of artefacts. After removing the film, edge rounding was still visible along with low development of polish or smoothing. The usewear is not diagnostic of the material

worked, but is consistent with other studies (e.g. Kamminga 1978, Fullagar 1998) that indicate slicing through soft material, and possible use as projectile elements or cutting tools.

A. B.

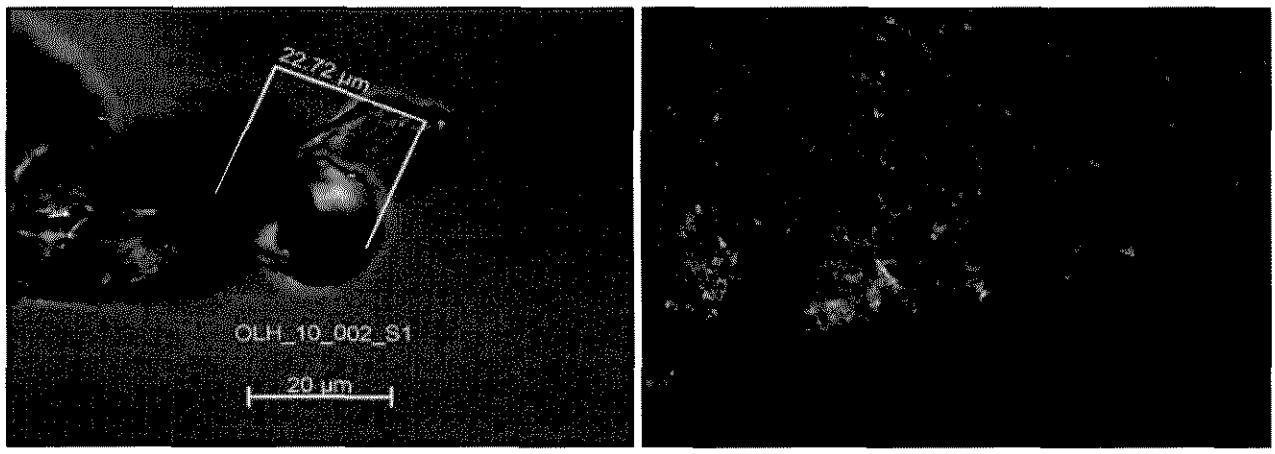

Figure 6.14: Residues and usewear on artefact OLH-TP1-10-001 from OLHTP1 at Riversleigh under low power magnification. A. starch grain. B. Scaring along the used edge (photos: J. Field and R. Fullagar)

Residues on OLH-TP1-10-001 included unidentified dark smears, scattered on all surfaces and starch granules of different sizes and shapes (Figure 6.14a). Starch granules from the backed edge were different from those removed from the chord with usewear. Further work is required on artefact function, but the preliminary hypothesis is that the dark smears, and small starch granules are associated with a resin haft.

Other usewear results indicate that a variety of tasks were likely completed with the sample of artefacts studied. For example OLH-TP1-9-033 is a retouched flake that has been used for piercing soft material, artefact OLH-TP1-10-153 was most likely used as a drill, with retouch and usewear present from both dorsal and ventral surfaces consistent with a turning motion. Artefact OLH-TP1-1-003 was used on soft plant tissue and artefact OLH-TP1-2-009 has usewear consistent with hafting

Shell analysis

The OLH TP1 contains a number of shell midden lenses. During excavation, at least three lenses were noted, and during lab analysis a further two lenses were identified. All shell types recorded from the OLH TP1 deposit are known to occur in the Gregory River. These are dominated by the bivalve *Alathyria pertexta spp.*, with low numbers of a second smaller bivalve and at least three types of gastropods: *Stenomelania densonensis*, *Melanoides sermygla sp*, and *Triora australis*, which are all found in freshwater stream environments and very closely resemble samples from southeast Asia (W. Ponder, Australian Museum, pers comm. 2002).

During the excavations it was noted that most shells were complete and in some places appeared to be cupped. The *Alathyria pertexta spp.* was found to be very friable during excavation. Analysis of shells by stratigraphic units shows four concentrations correlating to spits 8, 12, 14, and 19.

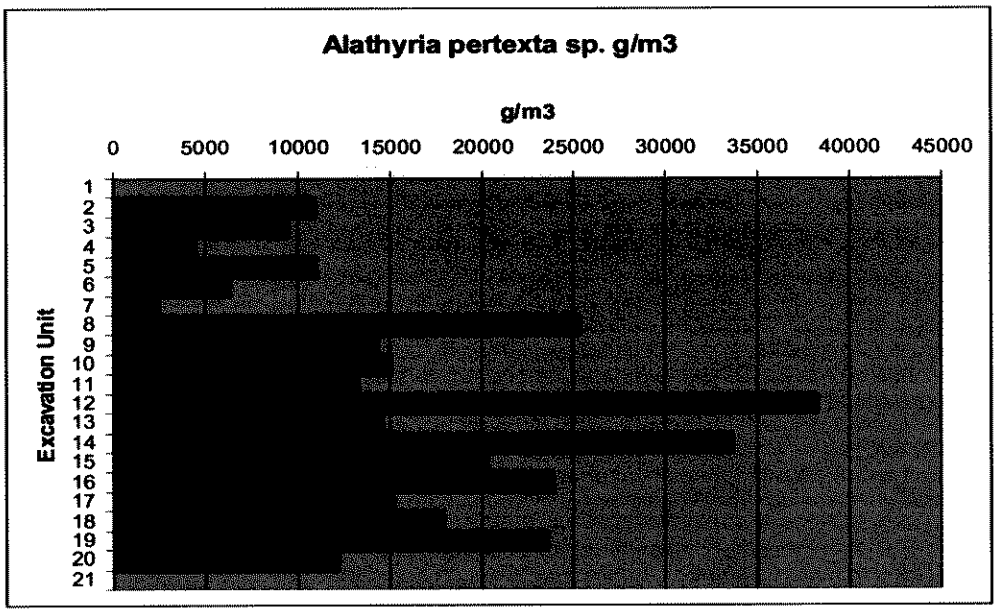

Figure 6.15: Concentration of *Alathyria pertexta spp.* mussel shell expressed as g/m3 for the OLH TP1 deposit, Riversleigh, northwest Queensland.

Shell Fragmentation

The number of individual specimens (NISP) and minimum number of individuals (MNI) were calculated for the shell assemblage. NISP was calculated on the basis of either 100% of the excavation unit sample or a random grab sample of 250 gm in weight in instances where the spit featured high shell discard. The abundance and fragmentation of shell (NISP counts) were found to be high in spits 9 - 19 of the deposit. The high discard rate of shell between spits 9 and 19 is also reflected in the MNI. Ratios of NISP : MNI and weight : MNI are commonly used as a measure of the extent of fragmentation of shell. Used here they support the conclusion that the OLH TP1 midden lenses were deposited in rapid succession in a short period of time.

Spit	total weight (g)	total NISP	MNI	weight : NISP	NISP : MNI	weight : MNI
1	36.5	521	0	521	n/a	n/a
2	336.6	1427	18	126	79	0.93
3	411.8	1384	22	81	63	0.93
4	232.2	878	7	378	125	1.66
5	360.5	1486	13	412	114	1.39
6	143.1	627	9	438	70	0.80
7	109.9	533	8	485	67	0.69
8	1076.2	2874	46	267	62	1.17
9	2660.4	7343	92	276	80	1.45
10	3184.8	7102	214	223	33	0.74
11	2784.0	13308	198	478	67	0.70
12	3060.3	12700	317	415	40	0.48
13	2785.2	8021	233	288	34	0.60
14	3419.1	6941	280	203	25	0.61
15	4275.6	10689	342	250	31	0.63
16	4548.1	14144	462	311	31	0.49
17	3040.8	9761	301	321	32	0.51
18	3108.7	5844	263	188	22	0.59
19	4128.0	13499	311	327	43	0.66
20	564.3	1761	83	311	21	0.34

Table 6.3: *Alathyria pertexta spp.* NISP, MNI and Weight ratios by spit for OLHTP1, Riversleigh, northwest Queensland.

The ratio of the weight of *Alathyria pertexta spp.* relative to MNI showed a significant trend towards larger shellfish for upper spits (see Figure 6.16). However, this trend can be explained by the decrease in the levels of fragmentation (NISP) relative to sample size. If the samples were restricted to those spits with the greatest concentrations of midden accumulation (in order to escape bias created by the upper spit sample sizes) then the ratio of weight to MNI is relatively constant at 0.6:1 (Figure 6.17).

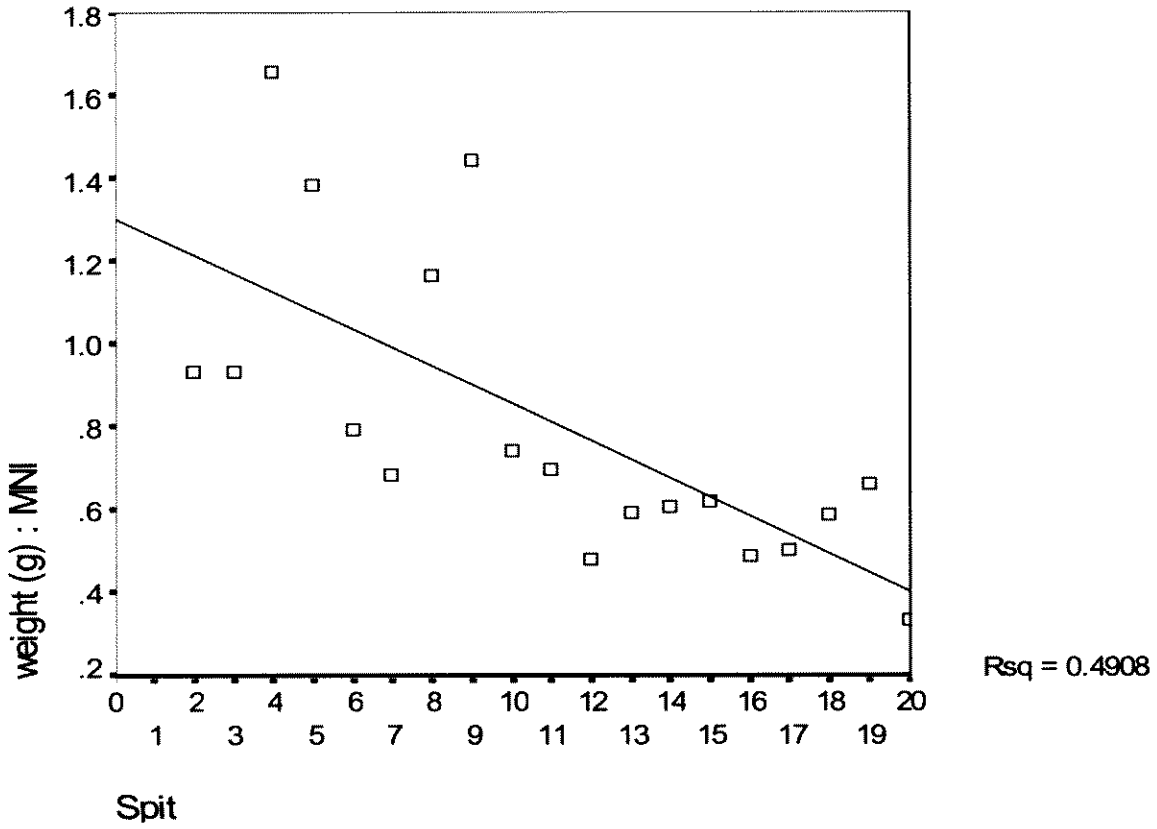

Figure 6.16: Weight of *Alathyria pertexta spp.* By spit relative to MNI for OLH TP1, Riversleigh, northwest Queensland.

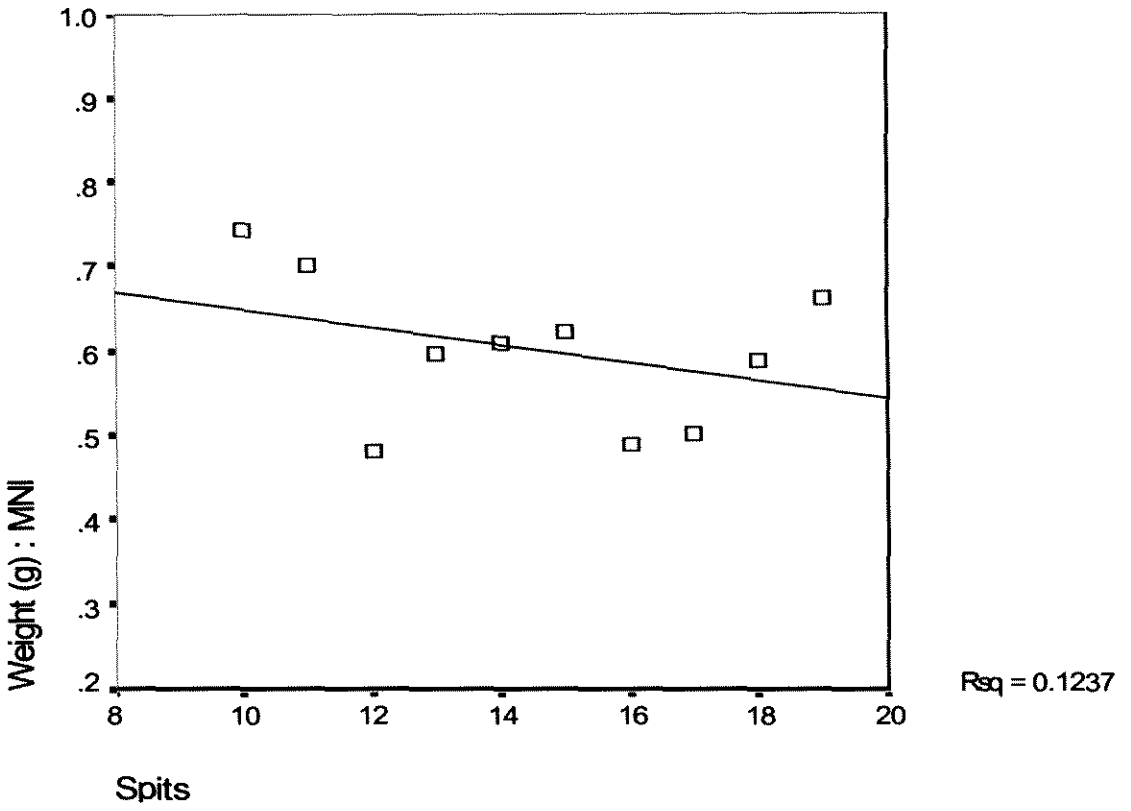

Figure 6.17: Weight of *Alathyria pertexta spp.* relative to MNI by spit for main midden phase of OLHTP1, Riversleigh, northwest Queensland.

Shell Size Analysis

Changes in mean valve size, and species abundance were calculated as possible indicators of differences in deposition rates. Valve lengths for all complete *Alathyria pertexta spp.* individuals were measured and indicate that there has been no significant change in size of shell with depth from surface. All *Alathyria pertexta spp.* are above the threshold for the sexual maturity of the species, implying human predation.

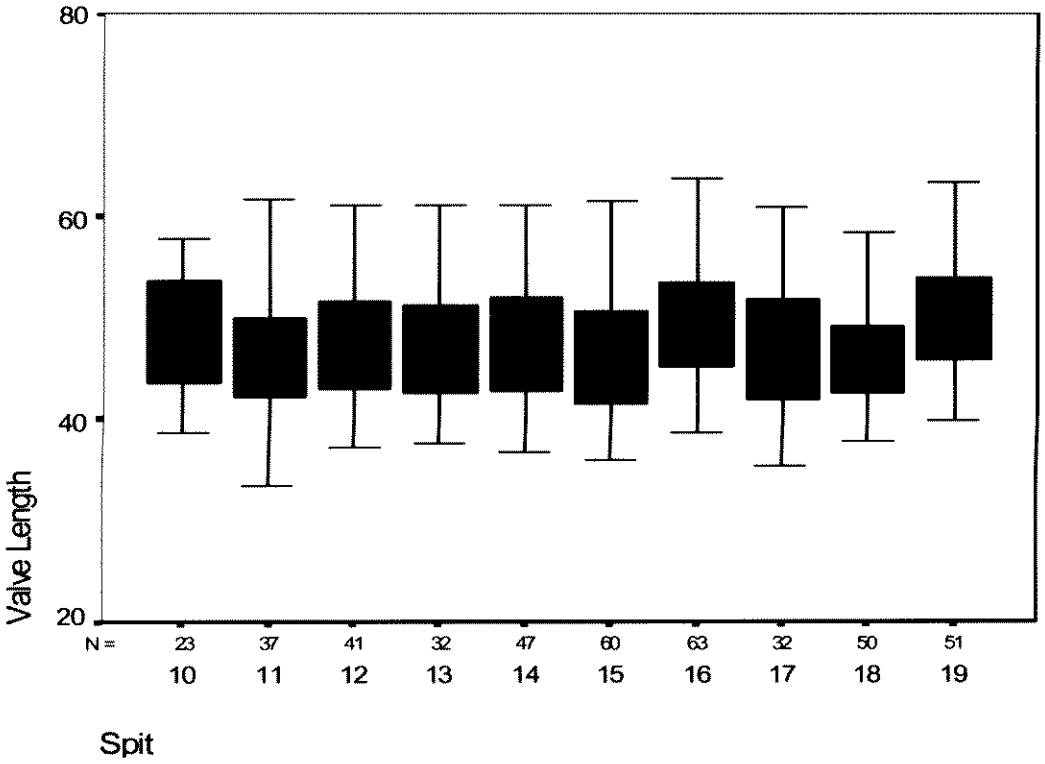

Figure 6.18: Box plot graph of the mean, mode and range of the valve lengths for all complete *Alathyria pertexta spp.* from spits 10-19 of OLH TP1, Riversleigh, northwest Queensland.

Summary

All of the data presented here provides a conclusive synthesis that OLH TP1 represents the remains of a rapidly deposited shell midden created by human agency. The site is dominated by one particular edible species of mussel shell – *Alathyria pertexta spp.* This species is present in very high numbers, and is represented by individuals that are well beyond a foodstuff threshold. The lithic assemblage is found mostly in association with the midden lenses. It is marked by high raw material richness and diversity in the retouched flake assemblage. Most flaked stone within the deposit is in the tertiary stages of reduction and much is broken. It is likely that the debitage relates to OLH locality operating as a large open camp site where re-tooling, implement maintenance and sharpening occurred. The OLH midden are interpreted to represent a residential base camp from which both provisioning and foraging occurred.

6.3.3 Gregory 8 - GRE8

Site Setting

GRE8 is located within the woodland environmental zone along the Gregory River gorge within the Riversleigh limestone plateau. The site is approximately 7 km from the intersection of the plateau and the eastern plain (Figure 6.19). The rockshelter is situated about 100 m above the southern bank of the Gregory River at the base of the limestone cliffs that form part of the Gregory River gorge. Immediately to the east of GRE8, the limestone cliffs give way to an expansive terrace associated with a large unnamed ephemeral stream, whilst to the west the limestone cliffs continue unbroken for approximately 2 km. The rockshelter is perched approximately 10 m above the Gregory River high water levels at the top of a limestone talus slope. This slope falls steeply to a series of channels and flood embankments associated with the Gregory River. At this point, the river is deep and slow moving with steep overhanging banks. No shallow pools or tufa dam areas occur within 5 km.

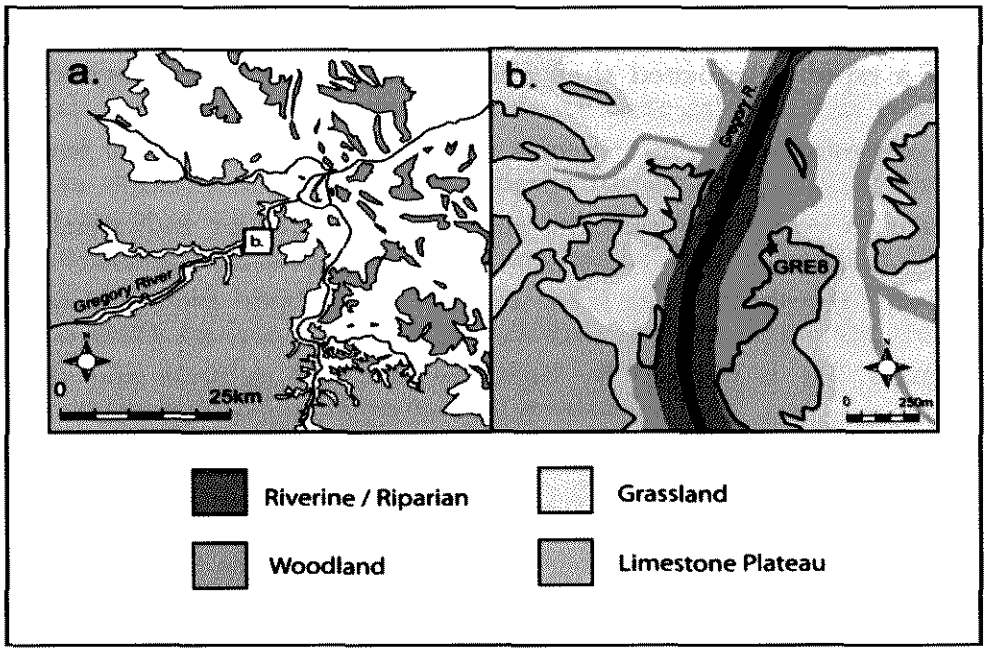

Figure 6.19: Location of GRE8 rockshelter, Riversleigh northwest Queensland. Map a. shows the general location of the area marked as b. Map b. details the location of GRE8 and its relationship to local patch types.

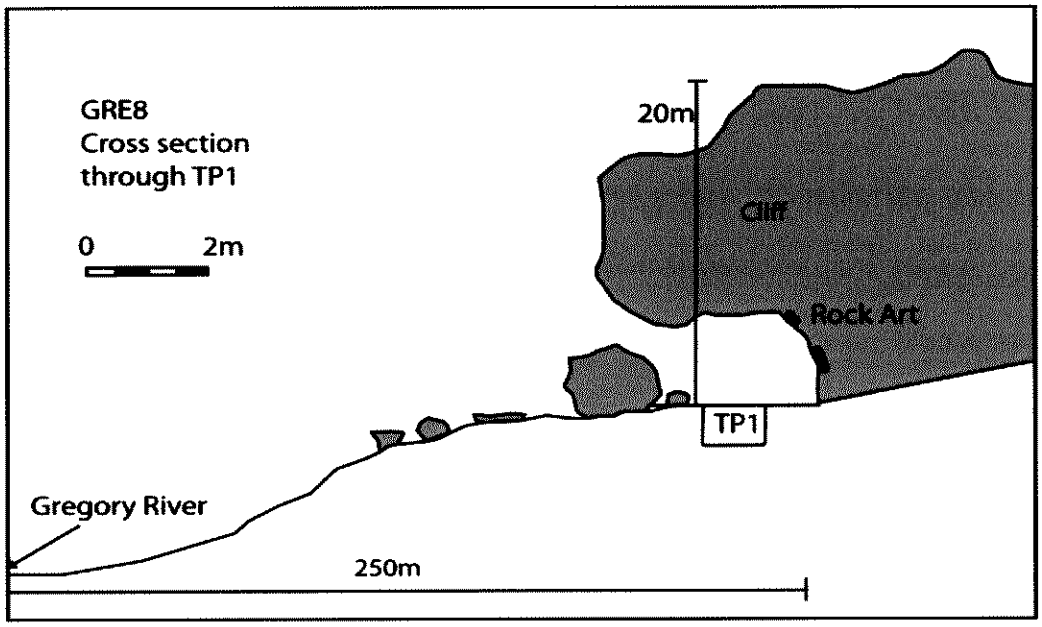

Figure 6.20: Profile of GRE8 rockshelter and position relative to the Gregory River at Riversleigh, northwest Queensland.

Within the GRE8 environs a variety of patch types are present. Riparian vegetation extends from the river bank for approximately 25 m, where it intersects with woodlands of various types. The woodland patch closet to the river is dominated by eucalypts and palms with a thick under-storey of smaller trees and vines. Woodlands closer to GRE8 are characterised by smaller *Acacia spp.* and grasses. A limestone plateau patch is located directly above GRE8, and features sparse grasses and a few small eucalypts. Local fauna include large and medium macropods and reptiles on the plateau, small mammals and birds within the woodlands, and fish, turtle and mussels in the river.

Site Description

GRE8 is a limestone rockshelter with a dry, flat floor area approximately 5 m x 2 m. At the rear of the rockshelter a small tunnel about 1.5 m in diameter slopes gently upwards before terminating about 5 m behind the primary shelter (Figure 6.21). A large boulder 2 - 3 m maximum dimension and the result of roof fall, sits at the front of the shelter. This

boulder has moved to this position some time after initial human occupation and has acted as a sediment trap.

Stone artefacts and shell are visible on the surface of the rockshelter floor and at the entrance beneath the large boulder. Three red, freehand painted, rock-art motifs are also visible on the rear wall of the shelter. Some of the limestone blocks, particularly outside the shelter, contain numerous chert nodules, which appear to have been flaked.

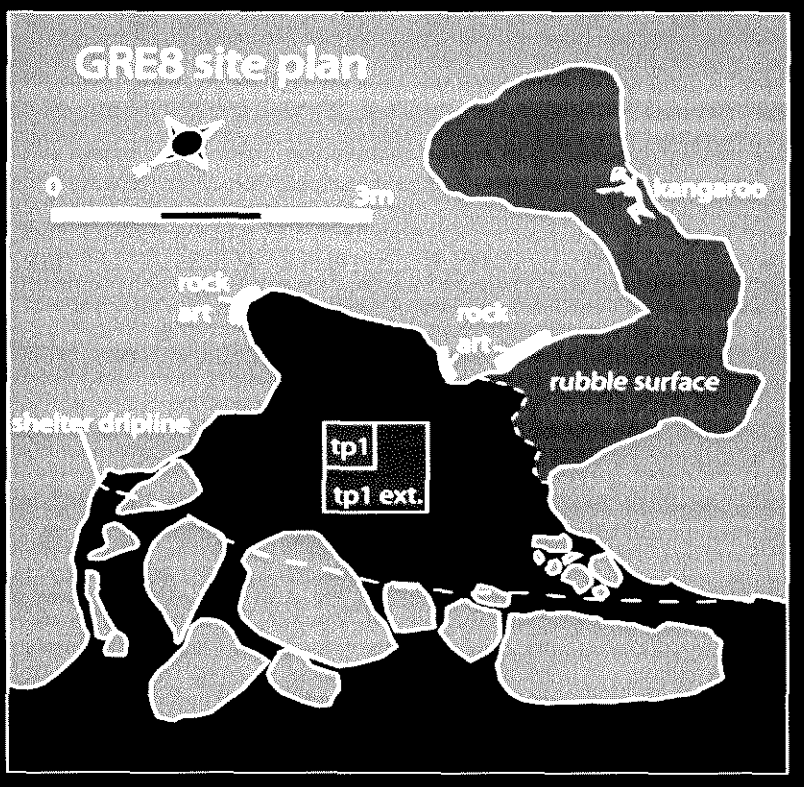

Figure 6.21: Plan of GRE8 showing the location of the test excavations, Riversleigh, northwest Queensland.

Excavation

Excavation of GRE8 was undertaken in July 2002 and June 2003. A 50 cm x 50 cm test pit was excavated in the centre of the shelter, just inside the dripline and behind the boulder at the entrance (Figure 6.20). Systematic excavation was undertaken by trowel, in 5 cm spits within stratigraphic units. This location was selected after taking into account the available headroom (ceiling height), likely depth of deposit, and protection from disturbance.

During June 2003 the square was expanded to a 1 m x 1 m area. Limestone bedrock was encountered at a depth of 57 cm below the surface. All excavated sediment was dry-sieved through 4 mm and 2 mm mesh, and preliminary sorting of material was completed in the field with the assistance of Waanyi community members.

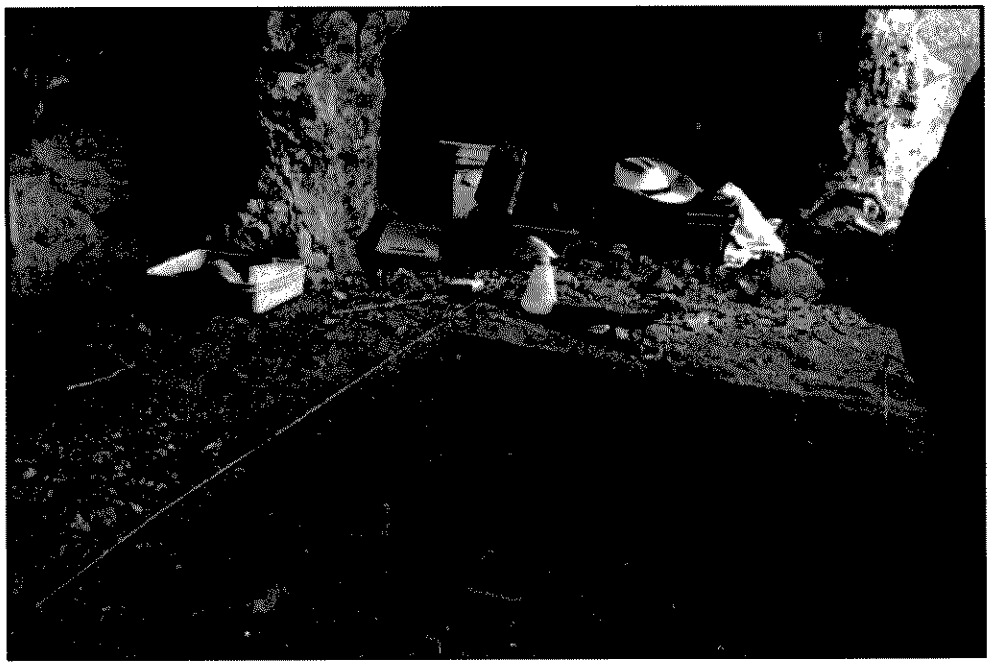

Figure 6.22: GRE8 looking to the south. TP1 is in the foreground and is almost completed.

Stratigraphy

The GRE8 deposit consists of three stratigraphic units overlying weathered limestone rubble and bedrock (Figure 6.23). Cultural material consists of stone artefacts and shell and is found throughout the deposit. Stratigraphic Unit 1 (0 - 5 cm) consists of very fine, light brown unconsolidated silts, possibly disturbed by kangaroos resting in the shelter Stratigraphic Unit 2 (5 ~ 32 cm) consists of compacted fine grey, sandy silt, which is comprised of a matrix of pedorelicts of calcareous clay and quartz grains mixed with some dolomite gravel derived from roof fall. Stratigraphic Unit 2 (SU2) contains stone artefacts, faunal skeletal remains, and mussel shell. A dense layer of *Alathyria pertexta spp.* was found in the lower 17 cm of SU2 and is referred to as Unit 2B. Stratigraphic Unit 3, (32 ~ 50 cm), consists of red/brown compacted sediment. The particle sizes are larger than the overlying units and consist of dolomite gravel and secondary carbonates. Chert artefacts, limestone rubble and pieces of 'ochre', probably derived from naturally occurring lumps in the walls of the shelter, are common throughout Unit 3. A continuation of dense mussel shell is found in the upper 15 cm of SU3 and is referred to as Unit 3A. A distinct feature of this lowest unit is the high incidence of carbonate encrustation on shells (*Alathyria pertexta spp.*) and chert artefacts (cf. Hiscock 1988).

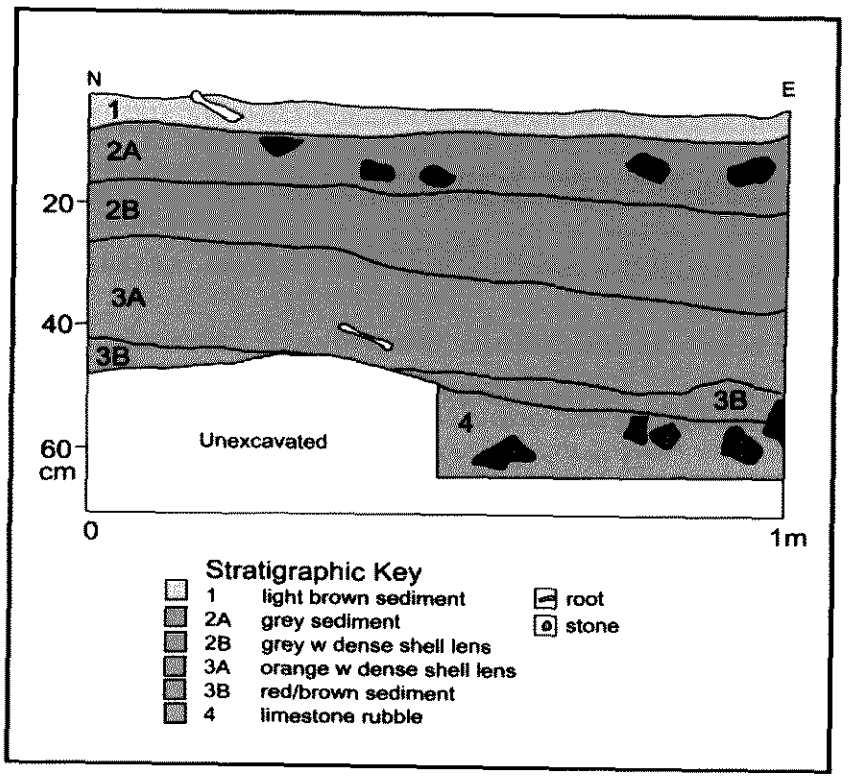

Figure 6.23: Section profile of the NE wall of GRE8 TP1 showing the locations of the three stratigraphic units and two dense shell layers (labeled as 2B and 3A).

The stratigraphy of GRE8 is very similar to the Colless Creek excavations of Hiscock (1988), where two stratigraphic layers were identified: a grey calcareous clay/quartz unit overlying an orange gravel unit. However, unlike GRE8, the Colless Creek stratigraphic units were separated by a lag unit that consisted of large gravels and stone artefacts. Sediment accumulation at GRE8 appears to be similar to that of Colless Creek Cave, where it was argued that most of the sediment entered the site through fissures above and in the rear of the rockshelter (see Magee and Hughes 1982). At Colless Creek, Unit B (the lower orange sediment) is believed to be similar sediment to that of Unit A but subjected to a long period of weathering (Hiscock 1988:167). No hearths were observed at GRE8 and charcoal was highly fragmented and rare throughout the deposit. While the *Alathyria pertexta spp.* appears in section as two concentrated lenses (SU 2B and 3A) it should be noted that it is present throughout the deposit.

Chronology

The GRE8 deposit has been dated using radiocarbon determinations on freshwater mussel shells. As there is a general absence of charcoal in the deposit and the mussel shell was recovered *in situ*, this material has provided the best medium for dating. Four radiocarbon determinations have been obtained: three conventional radiocarbon determinations (Wk 12228, Wk 12229, Beta 184341) and one AMS determination (Wk 11429) (Table 6.).

The age determinations for the GRE8 deposit were calibrated using Calib and Calpal programs and are expressed as the mean of age ranges to 2-sigma. The final radiocarbon dates have incorporated a local reservoir correction factor of 2,500 years (R. Drysdale pers. comm.).

Spit	Depth (cm)	Sample weight (g)	Laboratory Number	dC13	% Modern	Radiocarbon Age (yr BP)	Calibrated Age (yr cal BP)	Corrected Age (yr cal BP)
1	5	55	Wk 12228	-8.4 ± 0.2	60.2 ± 0.4	4,071 ± 50	4,530 ± 120	2,030 ± 120
5	24	30	Wk 12229	-8.6 ± 0.2	13.2 ± 0.2	16,249 ± 120	19,350 ± 660	16,850 ± 660
7	33	25	Beta 184341	-8.6 ± 0.2	Not supplied	28,090 ± 360	31,940 ± 800	29,440 ± 800
9	43	15	Wk 11429	-7.7± 0.2	1.0 ± 0.3	37,110 ± 2945	39,910 ± 2440	37,410 ± 2440

Table 6.4: Radiocarbon determinations for shell samples from GRE8 TP1, Riversleigh, northwest Queensland, showing radiocarbon ages as uncorrected, calibrated and corrected for reservoir effect.

An age-depth curve for the GRE8 deposit shows a relatively steady accumulation of sediments for the entire deposit (Figure 6.24). The average rate of sediment accumulation was also calculated in kilograms of sediment deposition per square metre per 100 years (Table 6.). Spits 1-5 represents a period between 13,500 years Cal BP and the modern period. During this period sediment accumulation was fairly constant at around

0.6kg/m²/100 years. Spits 6 and 7 show very low sediment accumulation rates of approximately 0.07 kg/m²/100 years and are coincidental with the termination of the Last Glacial Maximum. Below spit 7, sedimentation rates are lower than spits 1-5 but comparatively much greater than during spits 6-7.

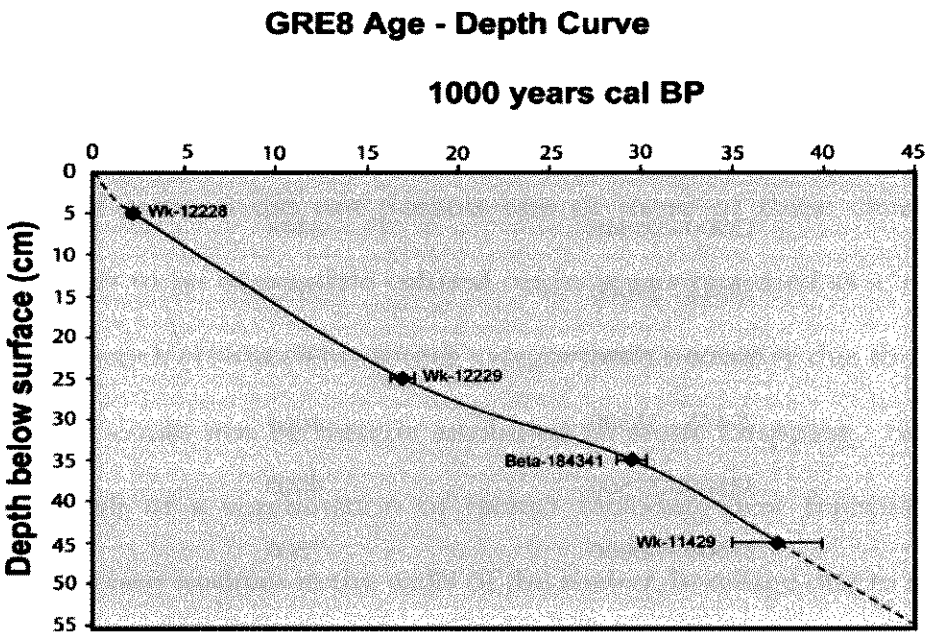

Figure 6.24: Age - depth curve for GRE8 TP1, Riversleigh, northwest Queensland.

On the basis of the radiocarbon determinations, stratigraphy, sedimentation rates and geomorphic history, the GRE8 deposit has been divided into five phases. Phase A is the period between first occupation and the commencement of the LGM, and correlates to spits 9-11 (and part of Stratigraphic Unit 3B). Phase B includes the LGM, between c. 18,000 BP and 30,000 Cal BP and correlates with spits 7 and 8 (stratigraphic unit 3A and part of 3B the lower midden deposit). Phase C (spits 5 and 6) spans the remainder of the Pleistocene (18,000 - 10,000 Cal BP). Phase D (spit 4 overlies this unit and covers the period between 10,000 and 5,500 Cal BP - the early to mid Holocene. Phase E (spit 3) represents the mid-Holocene period between 5,500 and 2,000 Cal BP. Phase F (spits 1 and 2) provides a record of the most recent 2,000 years.

Spit	Years BP	Time Span	Sediment Deposition kg/m²/100yrs
1	na	na	na
2	0 - 2302	2302	1.130
3	2302 - 5500	3198	0.560
4	5500 - 9700	4200	0.580
5	9700 - 13500	3800	0.590
6	13500 - 16848	3348	0.050
7	16848 - 24000	7152	0.080
8	24000 - 29436	5436	0.300
9	29436 - 33500	4064	0.880
10*	33500 - 37500	4000	0.970
11*	37500 - 45000	7500	0.690

*denotes sedimentation rates based on age-depth curve

Table 6.5: Time span and estimated sediment accumulation rates for each spit from GRE8 TP1, Riversleigh, northwest Queensland.

Phase	Spits	Age Range (Cal BP)	Period Represented
F	1, 2	0 - 2,000	Recent
E	3	2,000 - 5,000	Mid Holocene El Nino
D	4	5,500 - 10,000	Early Holocene
C	5, 6	10,000 - 18,000	Post LGM Pleistocene
B	7, 8	18,000 - 30,000	LGM
A	9, 10, 11	30,000 - 45,000	Colonisation

Table 6.6: GRE8 TP1 analytical phases.

GRE8 Stone Assemblage

In total, 1,899 flaked stone artefacts were recovered from the GRE8 trench. Identification of flaked stone artefacts and subsequent technological analysis was undertaken on the basis of presence of: *(i)* a positive or negative ringcrack, *(ii)* a distinctive or negative bulb of force, *(iii)* an eraillure scar in position beneath a platform or *(iv)* definite remnants of flake scars. These attributes indicate the application of an external force to a core (see Hiscock 2001b, 2002b). Flaked stone artefacts were classified into the categories of flake, core, or retouched flake. If material did not possess one or more of these characteristics but appeared superficially to be of possible cultural origin it was classified as a 'non-diagnostic fragment' as per Hiscock (1988). This fourth category was necessary due to the high levels of small pieces that could not be directly attributed to stone knapping. Such pieces are most likely the result of a combination of factors including heat fracturing in hearths, natural breakage of chert nodules in the walls of the shelter, breakage due to trampling, and knapping activities. Non-diagnostic fragments occur generally as a 1:1 relationship to humanly created stone artefacts.

There are marked temporal changes in the number and composition of the stone assemblage in the GRE8 deposit. The earliest phases of occupation (A and B) which occur from 30,000 Cal BP to 18,000 Cal BP, contain just 80 artefacts including 75 unmodified flakes and five cores including one large (632 g) multi-platform greywacke core. During phases C, D and E (between 18,000 Cal BP and 5,500 Cal BP), artefact discard increases to approximately 10 artefacts per 100 years. Discard rates decrease during the more recent periods. In summary, the rates of artefact discard in the GRE8 deposit point to low intensity occupation up to the end of the Last Glacial Maximum whereupon discard increases dramatically (ten fold) until about 7,500 Cal BP when discard reduces once more. (Table and Figure 6.25).

Spit	Phase	Volume	number of artefacts	number / kg	number / m³	number / 100 years	total weight (g)	average weight (g)
1 and 2	F	0.0566	337	9.8	5954.06	14.63	689.1	2.0
3	E	0.05	225	7.1	4500.00	7.03	397.5	1.8
4	D	0.0483	492	18.0	10186.34	11.71	765.1	1.6
5	C	0.04166	527	12.5	12650.02	13.86	733.8	1.4
6	C	0.0533	238	9.5	4465.29	7.1	323.15	1.4
7	B	0.045	26	0.7	577.78	0.36	58.9	2.3
8	B	0.055	35	1.5	636.36	0.64	72.1	2.1
9	A	0.066	12	0.3	181.82	0.29	42.3	3.5
10	A	0.05	4	0.1	80.00	0.1	2.3	0.6
11	A	0.045	3	0.1	66.67	0.12	7.5	2.5

Table 6.7: Summary of flaked stone artefact discard rates by spit and analytical unit GRE8 TP1, Riversleigh, northwest Queensland.

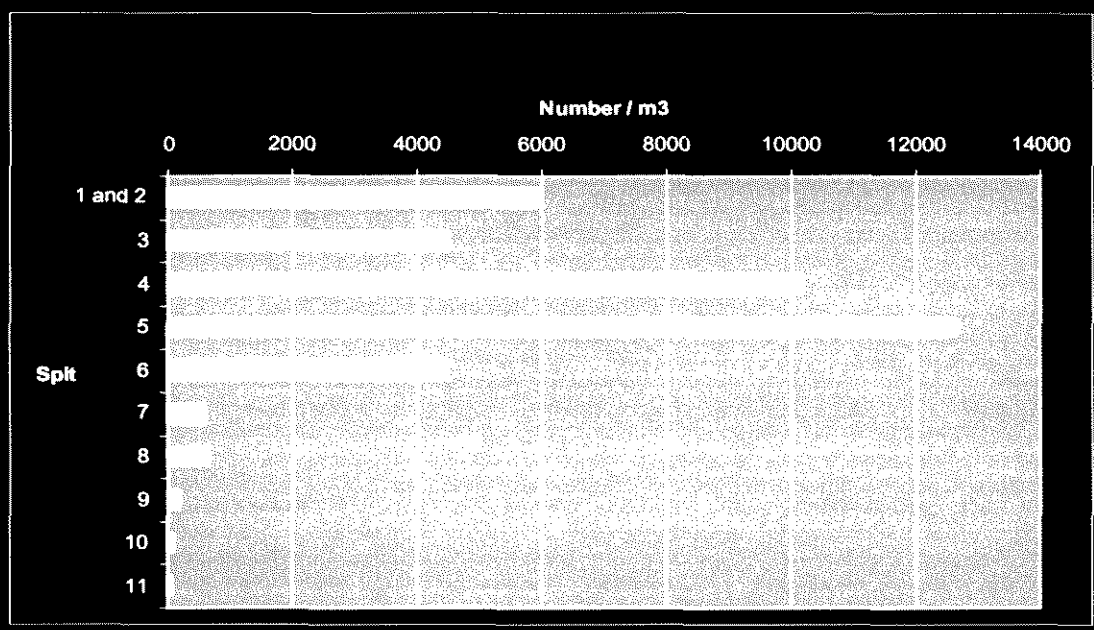

Figure 6.25: GRE8 TP1 flaked stone artefact assemblage showing number of artefacts discarded (/m3) by spit.

The GRE8 stone assemblage is dominated by unmodified flakes, comprising up to 90% of the total assemblage (excluding spit 10 where sample size is statistically too small). Cores account for c. 2% of the assemblage. Retouched flakes first appear in spit 6 at 17,000 Cal BP and form a small but consistent part of the assemblage after that time (Table 6.8 and Figure 6.26). During phases D and E (10,000 to 2,000 Cal BP) the relative percentages of retouched flakes and cores in the deposit reduce significantly before increasing in the most recent phase.

Spit	Number of artefacts	Percentage of Artefact Types in each Spit of GRE8		
		Flakes	Cores	Retouched Flakes
1/2	337	92.9	2.7	4.5
3	225	96.9	1.3	1.3
4	492	97.1	1.8	1.4
5	527	95.3	2.1	3
6	238	91.6	2.1	6.3
7	26	96.2	3.8	0
8	35	97.1	2.9	0
9	12	100	0	0
10	4	75	25.0	0
11	3	100	0	0

		Percentage of Artefact Types		
Phases	Total	Flakes	Cores	Retouched Flakes
F	337	92.9	2.7	4.5
E	225	96.9	1.3	1.3
D	492	97.1	1.8	1.4
C	765	94.1	2.2	4.1
B	61	96.7	3.3	0.0
A	19	94.7	5.3	0.0

Table 6.8: Percentages of different artefact types by spit and analytical phases in GRE8 TP1, Riversleigh, northwest Queensland.

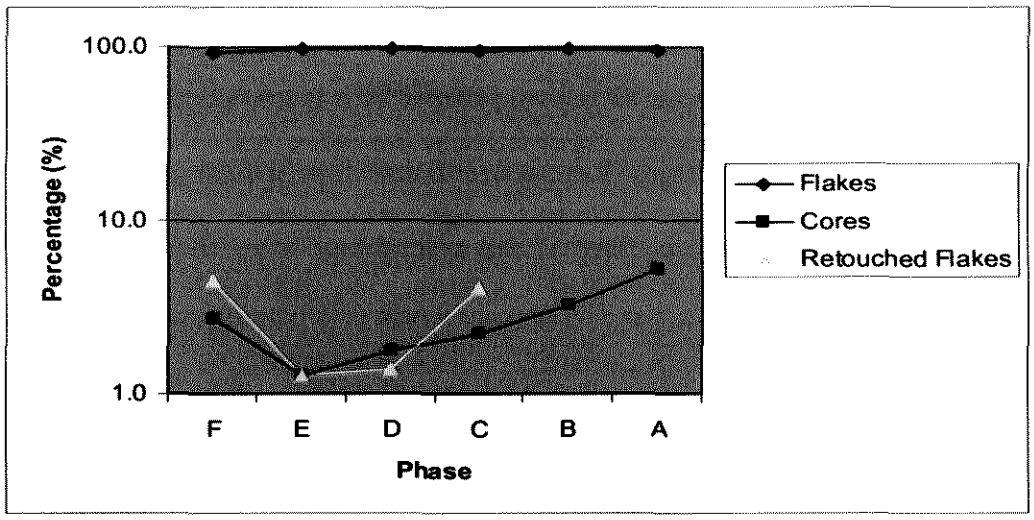

Figure 6.26: Logarithmic line graph of the occurrence by percentage of total of flaked stone types by analytical phases in GRE8 TP1, Riversleigh, northwest Queensland.

The mean weight of artefacts has been used as a potential indicator of different reduction strategies (Figure 6.27). Most variability in the mean weight of artefacts occurs in the early phases of occupation of the site with the heaviest artefacts occurring in spits 7, 8 and 9 between 18,000 and about 30,000 Cal BP. Sample size does not allow for a similar comparison with spits 10 and 11. After 18,000 Cal BP artefacts are notably lighter and generally up to half the weight of the earlier phases (Figure 6.27).

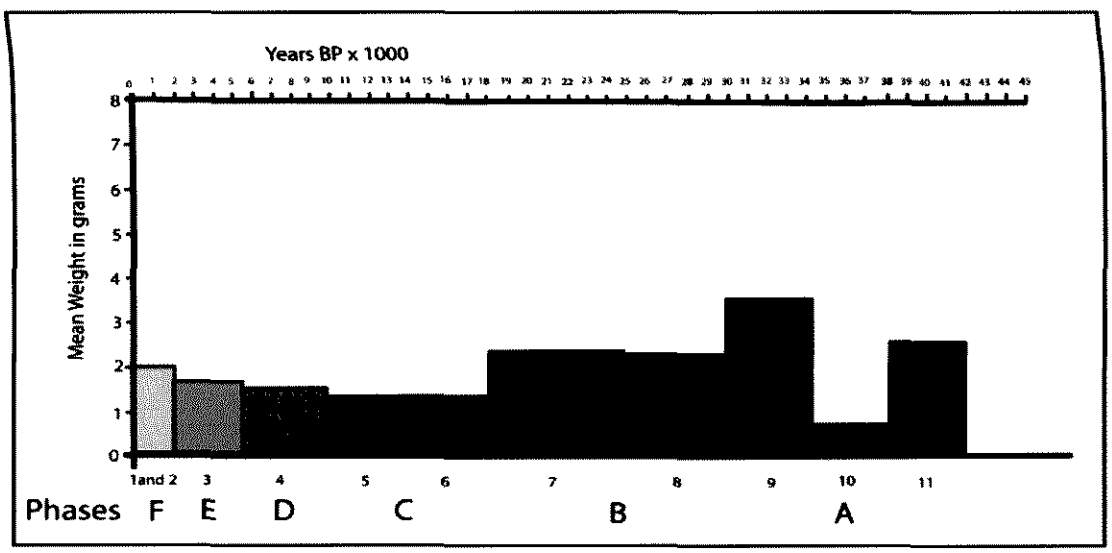

Figure 6.27: Graph of the mean weight of flaked stone artefacts by analytical phases and expressed by calibrated age for GRE8 TP1, Riversleigh, northwest Queensland.

Stone Procurement

Ninety five percent (95%) of the flaked stone assemblage at GRE8 consists of chert which has been obtained from either local river cobbles or nodules from nearby outcrops on the plateau. Other raw materials in the GRE8 deposit include greywacke, quartz, silcrete and one exotic volcanic material (an edge ground axe/hatchet on the surface of the shelter). These other raw materials are only present in very small numbers.

During phases A and B raw material richness at GRE8 is restricted to chert and very small numbers of artefacts (n=2) produced on quartz and quartzite. Of these, spit 9 (phase B) features a large quartzite core but no flakes produced from that core. During the post glacial Pleistocene phase C, five raw materials are present in the deposit, including the first occurrence of non-local greywacke which constitutes a small but significant component of the assemblage (n=14). This trend is continued up to the conclusion of phase D at 5,500 Cal BP, thereafter raw material richness reduces (Figure 6.28).

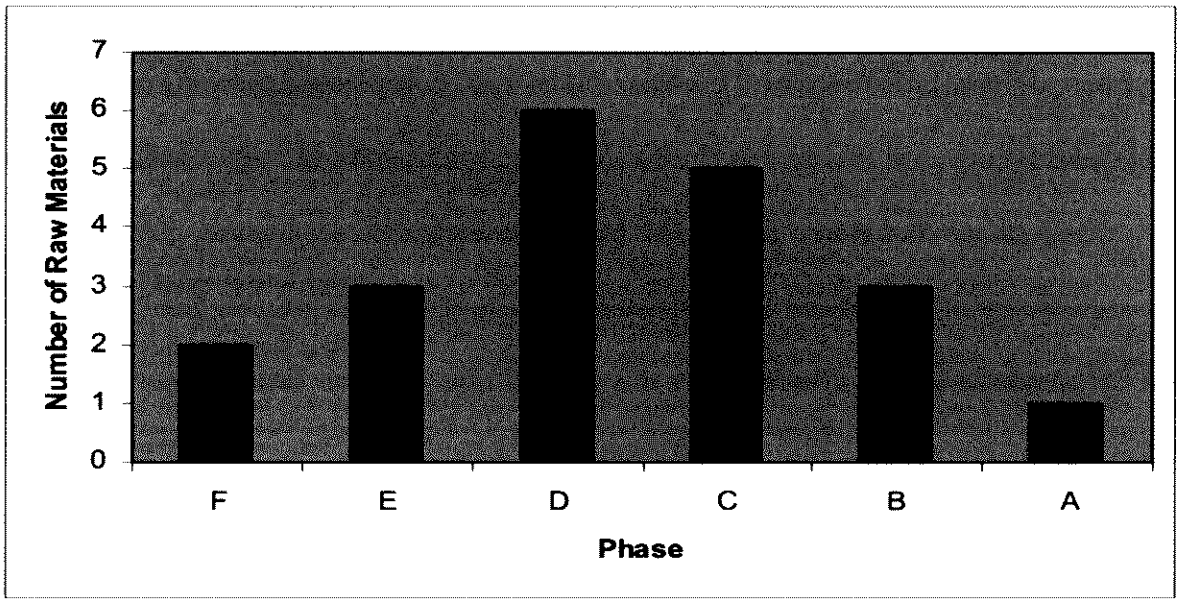

Figure 6.28: stone raw material richness for each phase at GRE8 TP1, Riversleigh, northwest Queensland.

Technological Changes

Analysis of the GRE8 assemblage has examined various measures of technological change (cf. Hiscock 1988). Breakage patterns, knapping techniques, raw material selection and the nature and length of reduction were all examined in this study.

Breakage

Breakage rates were calculated for flakes from the GRE8 deposit. Breakage included both transverse and longitudinal breaks, and were divided into proximal, medial, distal and marginal transverse fragments, and into proximal, distal and 'complete' longitudinal fragments. Longitudinally broken flakes account for less than 6% of all broken flakes, indicating that breakage is not due to errors in flaked stone manufacture within the site, but rather the result of another mechanism, most likely a combination of heat fracture and trampling. Measures of the ratio between longitudinal and transverse breakage for GRE8 showed that the ratio is small for phases A, B and C, but increases during the more recent phases D, E and F to almost 20:1.

Comparison of the ratio between broken flakes and complete flakes shows that during phases A and B (up until the end of the LGM) flake breakage is low; 26.3% in phase A and 11.9% during phase B. After the LGM breakage increases to around 50% of the total flaked stone assemblage. There are consistently more distal transversely broken flakes than medial or proximal flakes identified in the assemblage. These results also correlate well with those identified by Hiscock at Colless Creek Cave (1988:207).

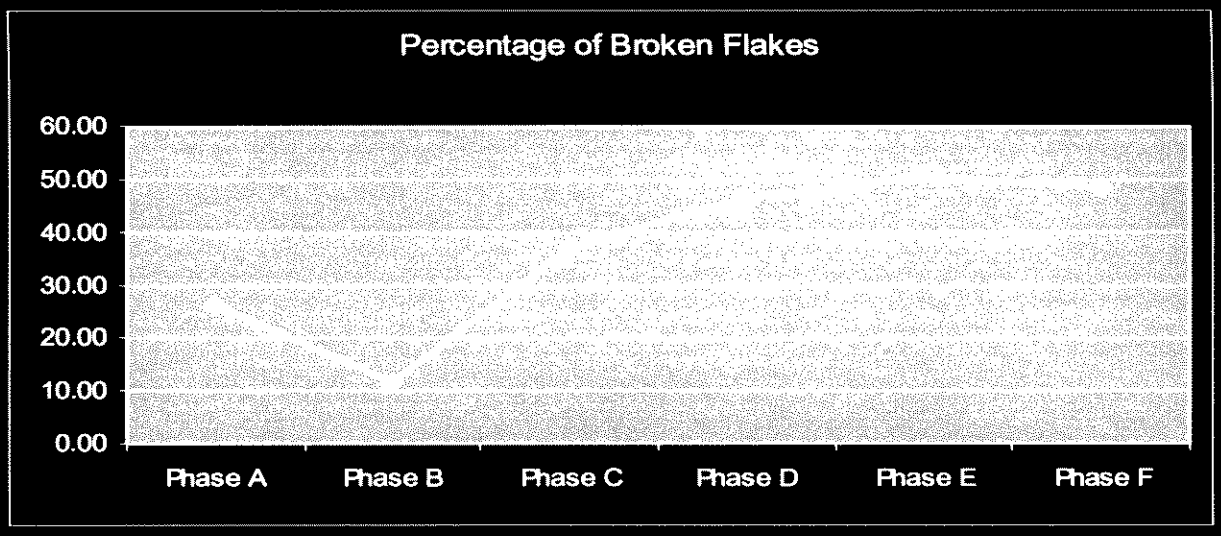

Figure 6.29: Percentage of broken flakes for each analytical phase in GRE8 TP1, Riversleigh, northwest Queensland.

	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
Percentage of flakes broken	26.32	11.86	37.40	46.39	50.61	48.66
percentage of proximal fragments*	0	3.39	11.96	15.40	14.29	17.91
percentage of medial fragments	5.26	1.69	5.09	5.46	8.16	3.74
percentage of distal fragments	5.26	5.08	13.23	16.76	19.18	20.86
percentage of longitudinally cone split fragments	5.26	0	3.81	1.17	1.22	0.27
percentage of fragments with both transverse and longitudinal breaks	0	0	2.03	2.92	1.23	1.87
Ratio of transverse to longitudinal breakage	2:01	6:01	5.2:1	9.2:1	17:01	19.8:1

Table 6.9: Percentage of different types of flake breakage in GRE8 TP1, Riversleigh, northwest Queensland.

The ratio between the rate of transverse breakage relative to complete flakes also provides an indicator of the intensity of the site use of GRE8 through time. Generally an inverse relationship between the ratio of transverse to complete flakes compared to sedimentation rates would be expected when sedimentation rates are high as there is less time to trample

and break artefacts. If this relationship does not hold, then an increase in site use is inferred. Comparison with sediment accumulation rates for the deposit at GRE8 showed that in spits 6, 7 and 8 this relationship stands, but in spits 1 and 2, 3, 4, and 5, the ratio of transverse to complete flakes, compared to sediment accumulation, is very high. This indicates that GRE8 was more intensively occupied after about 13,000 Cal BP (Figure 6.30).

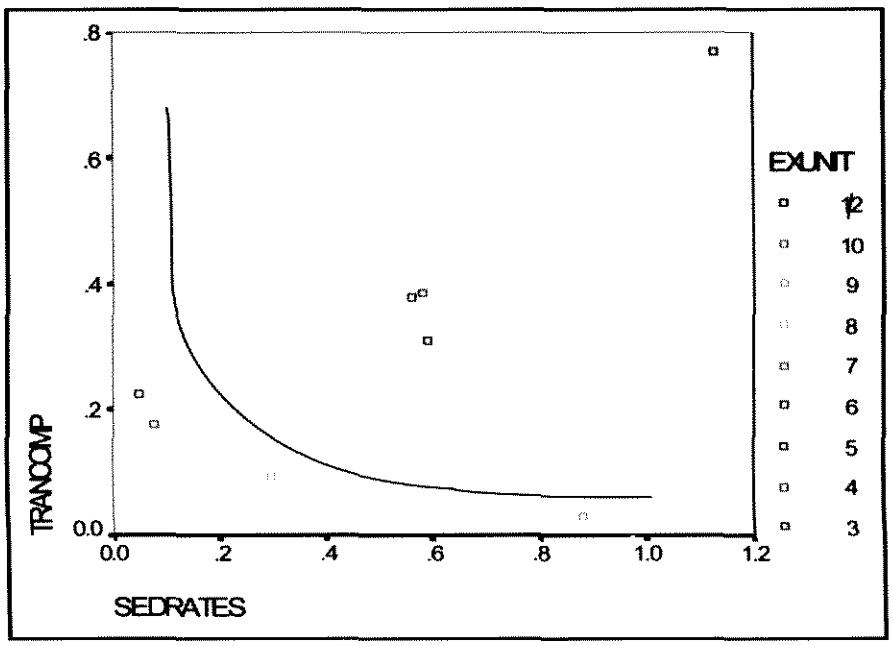

Figure 6.30: Comparison between the ratio of transversely broken and complete flakes and sedimentation rates cm / 100 yrs for GRE8 TP1, Riversleigh, northwest Queensland.

Knapping and reduction

Core reduction

Seventeen cores were recovered from the testpit excavation: 16 chert cores and one large multiplatform greywacke core in spit 9 (623 g). The mean block size of the chert cores was 13.7 cm^3 (S.D. = 8.15 cm^3). Cores had been rotated between 1 and 5 times (on average twice). An average of 5.37 negative scars were recorded on the core assemblage (range was 1 – 16). Although the sample of cores is very small, most were discarded during phase D (5,500 - 10,000 Cal BP, n = 8).

	number of cores	av. wt. (g)	av. block size (cm3)	number of flake scars	av. length of longest scar (mm)
Phase F	3	13.33	19.03	6.33	18.51
Phase E	1	53	12.12	2	23.1
Phase D	8	14.61	9.16	5.5	18.06
Phase C	3	28.63	39.43	2.66	18.43
Phase B	0	0	0	0	0
Phase A	1	31.6	29.95	13	27.6

Table 6.10: Mean weight, block size, number of flake scars and average length of the longest scar for cores in GRE8 TP1, Riversleigh, northwest Queensland.

Flakes

All flakes in the assemblage were produced using direct percussion, and no evidence of pressure flaking or indirect percussion was observed. Bipolar flaking occurred only on retouched flakes from the upper spits, and is represented by a very small component of the assemblage. As with Colless Creek Cave, changes in knapping technique do not appear to account for changes in artefactual material.

Analysis of stone reduction involved metrical examination of the location and force of blows to cores and flake platforms, the nature of core maintenance, and decortation processes. The relative percentage cortical cover on the dorsal surfaces of complete flakes is an indication that the majority of flakes possess no cortex. Small flakes dominate the assemblage. In phases B and E, the relative proportion of flakes with little or no cortex is significantly higher than during other phases. Phase B (the glacial period) flakes with 0% cortex account for 81% of the assemblage and 73% during phase E (the mid Holocene).

Complete flakes with 100% of their dorsal surfaces covered with cortex (primary flakes) account for 5-7% of all flakes for phases A and B, increase during the post glacial Late Pleistocene and Holocene.

% Cortex on flakes	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
0 cortex	68.4	81	67.1	66.5	72.7	68.3
< 25%	10.5	8.6	9.4	10.3	6.5	5.6
26-50%	15.8	1.7	5.2	5.5	5.1	6.3
51-75%	0	0	3.1	3.2	0.5	5.3
76-99%	0	1.7	5.5	2.7	1.4	4.4
100%	5.3	6.9	9.7	11.8	13.9	10
number of flakes	19	58	745	474	216	319

Table 6.11: Cortex on flakes by phase in GRE8 TP1, Riversleigh, northwest Queensland.

Applied Force

Knapping precision can be assessed by documenting the types of flake terminations, the prevalence of shattered surfaces, and the area of flake ventral surfaces. Figure 6.31 shows a box plot of the average ventral surface area of complete chert flakes for each spit of GRE8 TP1 (spits 10 and 11 have been excluded from analysis due to sample size). Chert flakes were found to be less than 5 cm^2 in area and never greater than 7 cm^2, reflecting the commonly small dimensions of the chert cores. Analysis of ventral surface area shows that during spits 5 and 6 (phase C) blows were of less force than during other periods. During this phase platform size was also smaller indicating lesser force was applied.

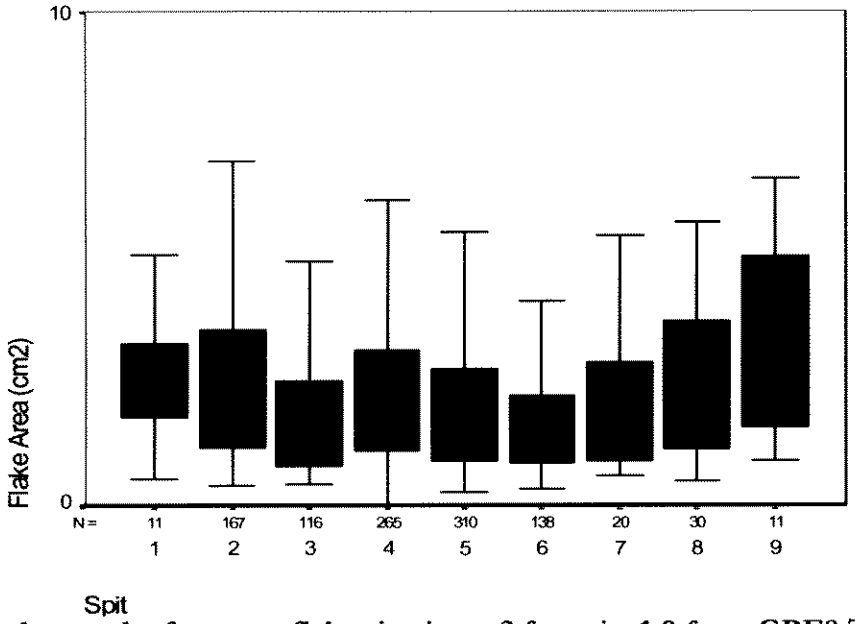

Figure 6.31: Box plot graph of average flake size in cm2 for spits 1-9 from GRE8 TP1, Riversleigh, northwest Queensland.

The relative percentages of termination types present on complete flakes from the GRE8 TP1 assemblage is presented in Table 6..12. Aberrant terminations are greatest during phases C and D (17,000-5,500 Cal BP). During these phases the rate of hinge terminations increased, and correlate with the reduction in knapping force determined by ventral surface area.

	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
Feather/axial	81.25	89.09	77.34	77.37	87.21	83.75
Hinge	12.50	5.45	14.42	14.21	6.40	7.58
Step	6.25	5.45	7.61	6.84	6.40	8.66
Outré passé	0	0	0.63	1.58	0	0
N =	16	55	631	380	172	277

Table 6.12: Relative percentages of different termination types for the analytical units of the GRE8 deposit (calculations based on sample size of MNF n=1531), Riversleigh, northwest Queensland.

Location of the Force of Application

The location of blows relative to the edge of the core can affect the size and shape of the resulting flakes (Hiscock 1988:213). Two of Hiscock's four measures of force of application have been applied to the GRE8 data: *(i)* the type of platform surface to which the blow is made, and *(ii)* the proximity of the blow to the core edge. As with Colless Creek Cave, platforms were never prepared by faceting or grinding, but most often through the removal of a single flake. Unprepared cortical platforms consistently account for 6-9% of flakes, except for during phase B (30,000-18,000 Cal BP) where they account for just 1.8% of flakes. During this phase there is an increase in the incidence of flakes that feature a single flake scar platform. There is also an increase in the rate of multiple flake platforms during phase D (10,000-5,500 Cal BP).

Placement of blows with respect to the core face was measured by the width of flake platforms perpendicular to bulbar scars. This analysis indicates that knapping became more accurate through time with an average thickness of platforms of almost 9 mm during phase A, reducing steadily until the recent phase F unit where average platform thickness was almost half of the original at 4.6 mm (Table 6.13). This trend accords well with an increasing propensity for overhang removal on core platforms prior to flake detachment. During phases A, B and C there was little or no core preparation in respect of overhang, but during the later phases D, E and F over 10% of all flakes show evidence of overhang removal.

Platform Surface	%					
	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
indeterminate	0	0	2.09	2.5	3.1	4.6
cortical	7.1	1.8	6.1	7.3	6.2	8.7
single flake	92.8	94.4	83.3	79.7	84.5	81.6
multiple flake	0	3.7	6.4	9.8	5.4	5.1
shattered	0	0	2.1	0.6	0.8	0
n	14	54	527	316	129	196

Table 6.13: Relative percentages of platform types for the GRE8 TP1 assemblage, Riversleigh.

Platform Features	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
% flakes with overhang removal	0	4	6	13.25	14.65	11.2
average platform thickness (mm)	8.8	5.5	5.2	4.7	4.7	4.6
total number sampled	14	50	448	264	116	178

Table 6.14: Relative percentages of platform features recorded for the GRE8 TP1, Riversleigh, northwest Queensland.

A comparison of the average length to width of all complete chert flakes shows a trend towards more elongated flakes through time. Flakes in the lower spits (5-9) are generally grouped together with a length to width ratio of less than 1.2:1, whereas flakes in the upper spits (1-4) all group around a ratio of 1.3:1 (Figure 6.32). The exception to these trends is in spit 8 where flakes are considerably longer relative to width when compared to spits 7 and 9.

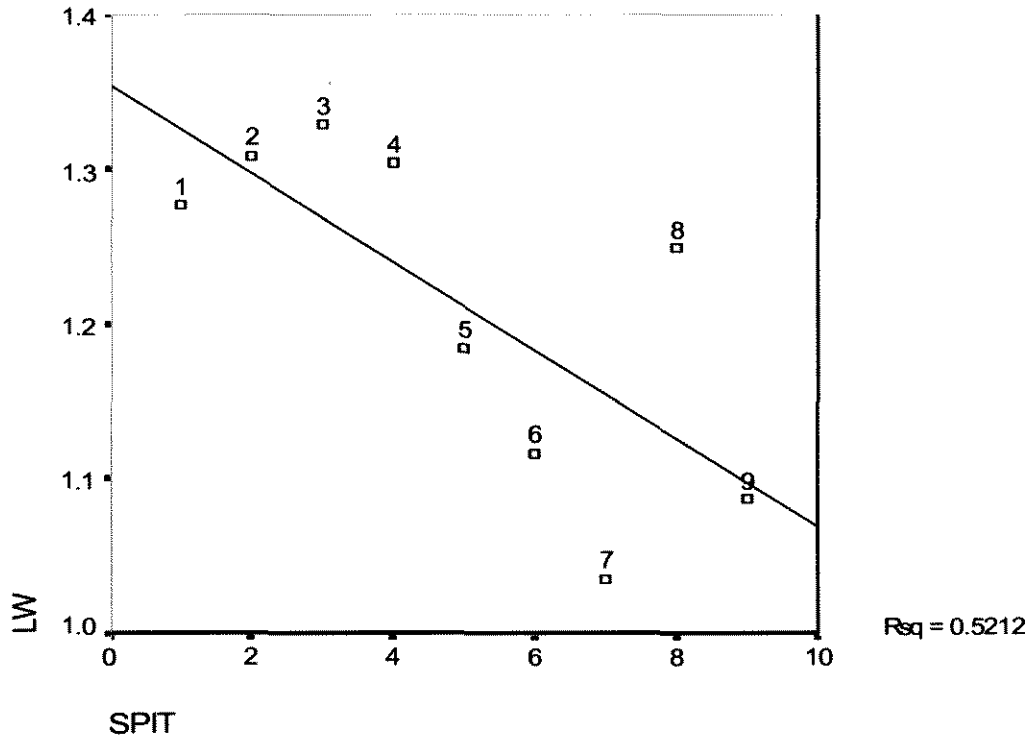

Figure 6.32: Scatter gram plot of the ratio between average proximal length and average proximal width of complete chert flakes by spit for GRE8 TP1 Riversleigh, northwest Queensland.

Retouched Artefacts

Retouched flakes appear in phase C of the deposit (spit 5) at a depth of approximately 27 cm, and include two chert backed artefacts, the lowest of which is in spit 5, dated to 13,000 Cal BP (Slack *et al.* 2004). A large quantity of amorphously retouched flakes also occur at this time. All feature less than five non-invasive scars which occur as either as distal retouch, or in three examples, as notches on one of the lateral margins of the flake. During phase D (10,000-5,500 Cal BP) the retouched assemblage becomes more diverse and features the appearance of a tula and two unifacial points at the base of spit 4 (7,500-10,000 Cal BP). Overall there are few retouched artefacts in the assemblage until the recent phase F sediments where diversity is at its highest but abundance is still low (Figure 6.33).

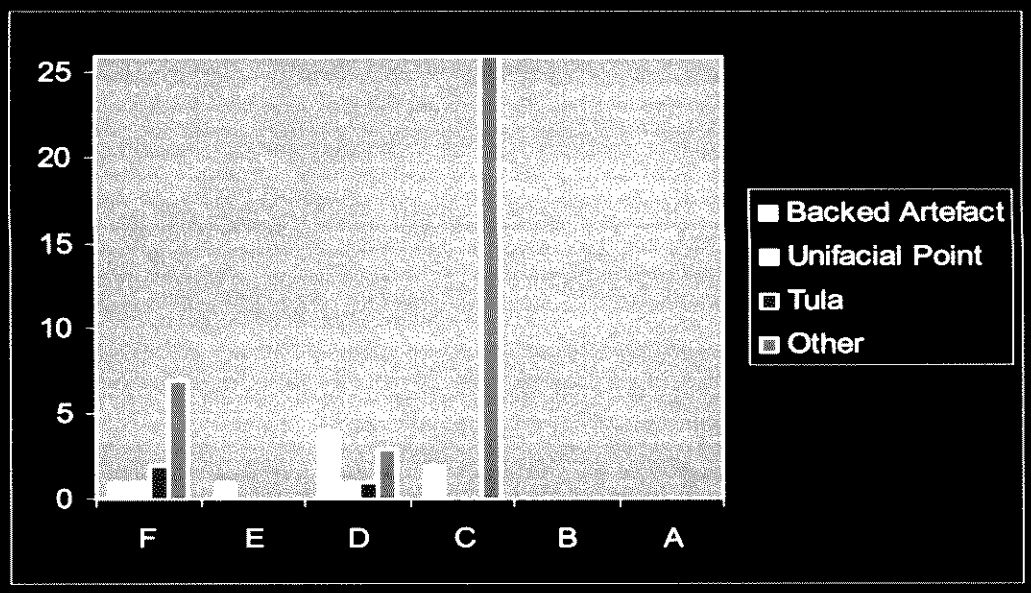

Figure 6.33: Frequency histogram of different classes of retouched artefacts in the GRE8 TP1, Riversleigh, northwest Queensland.

Usewear and residue studies

Usewear and residue studies were completed for the entire retouched artefact assemblage by Veerle Rots and Richard Fullagar. These artefacts included amorphous retouched flakes, backed artefacts, tulas and points. The results of usewear analysis indicate that some artefacts were definitely used whilst other formal implements were not (for example backed artefacts GRE8-1-063, and GRE8-2-1121). Backed artefact GRE8-2-1122 had numerous, very small step scars on one end indicating impact damage.

Spit 4 of the deposit is dated to between 5,500 and 10,000 Cal BP and features numerous retouched flakes including backed artefacts and a tula. These artefacts predate the known antiquity of similar types by many thousands of years. Usewear analysis concentrated on these artefacts.

Artefact GRE8-4-001 is a chert backed artefact, approximately 19 mm maximum length and 9 mm maximum width. Backing retouch is almost continuous with initiations from both directions. The artefact has been snapped at one end, and that edge has less use wear

than along the chord, which has slight edge rounding and a few very small bending scars. It is thought that the artefact broke during use. The chord also features slight polish or smoothing that is not diagnostic of contact material, but is consistent with other studies (e.g. Kamminga 1978, Fullagar 1998), which indicate slicing through soft material, and possible use as projectile elements or cutting tools.

Artefact GRE8-2-1321 is a tula slug, from a level dated between 2,000 and 5,500 years BP. It has been hafted and used, and a residue of orange/red plant material that might indicate hafting resin is present near the platform. GRE8-4-1004 is a classic woodworking tula recovered from an horizon dated to between 5,500 and 10,000 Cal BP. It features a cortical platform, 5 cm of retouch consisting of overlapping feather and bending terminations, 5-6 scars of which are invasive. Usewear is present on the distal end of the flake and the dorsal surface has spots of plant/resin near the platform and in the middle whilst the ventral surface features dark brown smears/spots. A unifacial point GRE8-4-010 which occurs in the same level features abrasive smoothing, including polish that indicates wood, and hafting resin.

Backed artefact GRE8-4-018 (spit 5) is a chert flake with crazing from intense heat. Its maximum length is c. 19 mm and width is c. 7 mm. A dorsal ridge separates two scars but direction of flake removals could not be determined with any confidence. Sharp tips at both ends are broken and backing retouch initiated from the ventral surface is continuous along the length of the artefact. Backing retouch initiated from the dorsal surface is continuous, but only present at one end. In plan view the chord is slightly concave and has slight edge rounding and contiguous use scarring with feather and bending terminations. There are also step and cleft scars. The chord displays usewear consistent with the other backed artefacts. Greasy films and starch granules were visible under reflected light microscopes and burning was indicated by crazing.

Faunal Assemblage

Vertebrate Fauna

The faunal assemblage at GRE8 includes both terrestrial and riverine animals, including small and medium macropods, turtle, fish, and fresh water mussels. A total of 749 fragments of bone were recovered from the excavation, including seven fragments of bone from the surface of the rockshelter. Bones that could not be identified to species were recorded as 'large mammal' (cf. *Macropus rufus/Macropus giganteus*), 'medium mammal' (cf. *Macropus eugenii/Trichosurus vulpecula*). 'Other' was ascribed where it was not certain from which taxon the fragment was derived. The calculation of the species recovered from the site was done using the Number of Identified Specimens (NISP) (Table 6.). All fragments of bone were counted including elements from the vertebral centrum, ribs and long bone shafts. The minimum number of individuals (MNI) was not calculated due to the small number of elements identified to species.

In overall terms, bone was not weathered, with most bone recorded as stage 1 (after Berensmeyer 1978). The bones that showed the greatest amount of weathering consisted of the material recovered from the surface of the excavation. Within the lower five spits there was a significant increase of calcium carbonate encrustation on bones. A small number of bones had also been burnt, and consisted of unidentified and very small fragments from spit 4 (10 fragments) and spit 5 (9 fragments).

The majority of mammal elements were medium sized macropodidae, and are likely to be the same species, particularly the cranial material, cf. *Macropus eugenii* (tamar wallaby) and *Wallbia bicolour* (swamp wallaby). None of the bones were any larger than *Macropus eugenii*, the majority falling between the two in size. Two varanid (lizard) vertebrae were identified from spit 2 and 9 and consisted of a partial and complete vertebra (respectively). Turtles were represented by carapace, which were very fragmented.

Fauna NISP	Spit								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mammals									
Small		193	108	111	44	60	42	30	
Medium	2	12	3	2	6	2	5	4	8
Large	1		1						
Lizard		1							1
Turtle		19	17	25	38	8	2	1	
Fish			4						
total	**3**	**225**	**133**	**138**	**88**	**70**	**49**	**35**	**9**

Table 6.15: NISP calculations for the vertebrate faunal assemblage GRE8 TP1, Riversleigh, northwest Queensland.

The faunal analysis indicates some trends in resource exploitation in the history of GRE8. Small mammals appear to have been the most common terrestrial fauna present at GRE8 with only very small numbers of large and medium mammals. The relative abundance of small mammals appears to increase through the sequence with a shift in spit 5 (c. 13,000 Cal BP) where there appears to be a clear, relative increase in the discard of turtle remains (Figure 6.34).

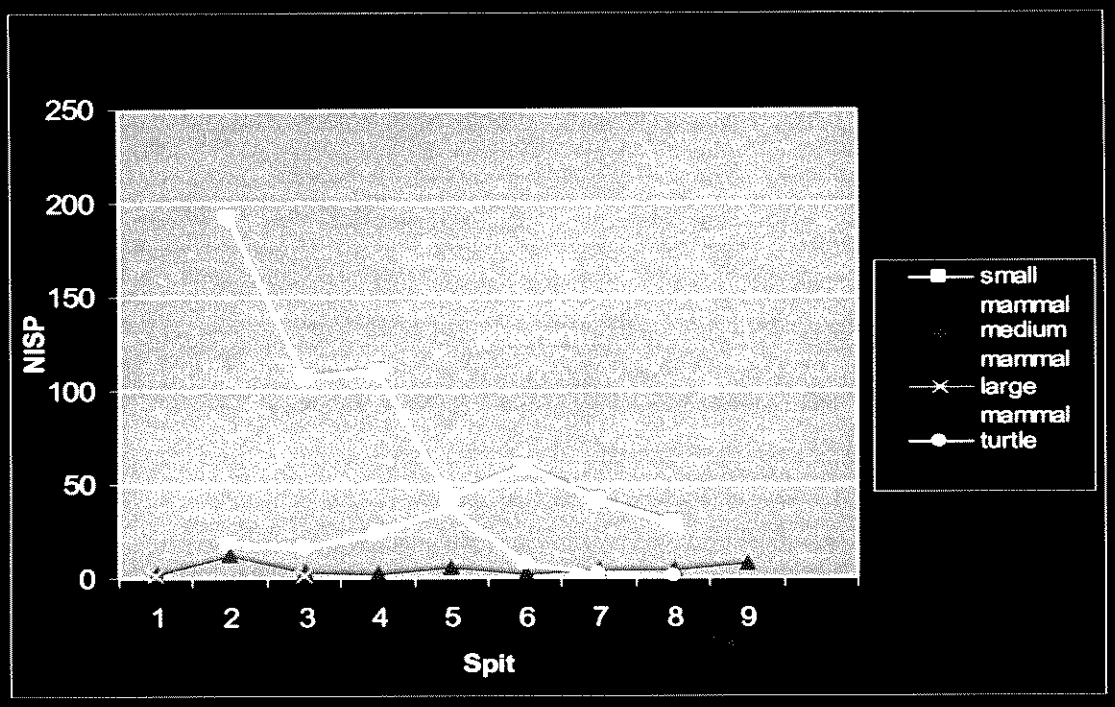

Figure 6.34: Changes in abundance of vertebrate fauna by spit from GRE8 TP1, Riversleigh, northwest Queensland.

Invertebrate Fauna

The invertebrate fauna at GRE8 consists of freshwater mussels and gastropods, as found in the nearby OLH midden. Freshwater mussels consist entirely of *Alathyria pertexta spp.* (Figure 6.35). Gastropods are represented in low frequencies through most of the deposit but never amount to more than 5 g in any excavation unit. Their presence can be broadly correlated with increases in mussel shell. Gastropods were most likely brought into the site attached to mussel shells.

Alathyria pertexta spp. first appears in spit 8 and then increases markedly to peak between spits 5 and 7 (c. 100 kg per m^3), between 30,000 Cal BP and 13,500 Cal BP. The peak in discard relates in stratigraphic units 2B and 3B corresponds to the dense shell lenses visible in section (this analysis shows that there is no break in shell discard between these two

units). *Alathyria pertexta spp.* continues to be represented but at a greatly reduced level in the upper spits.

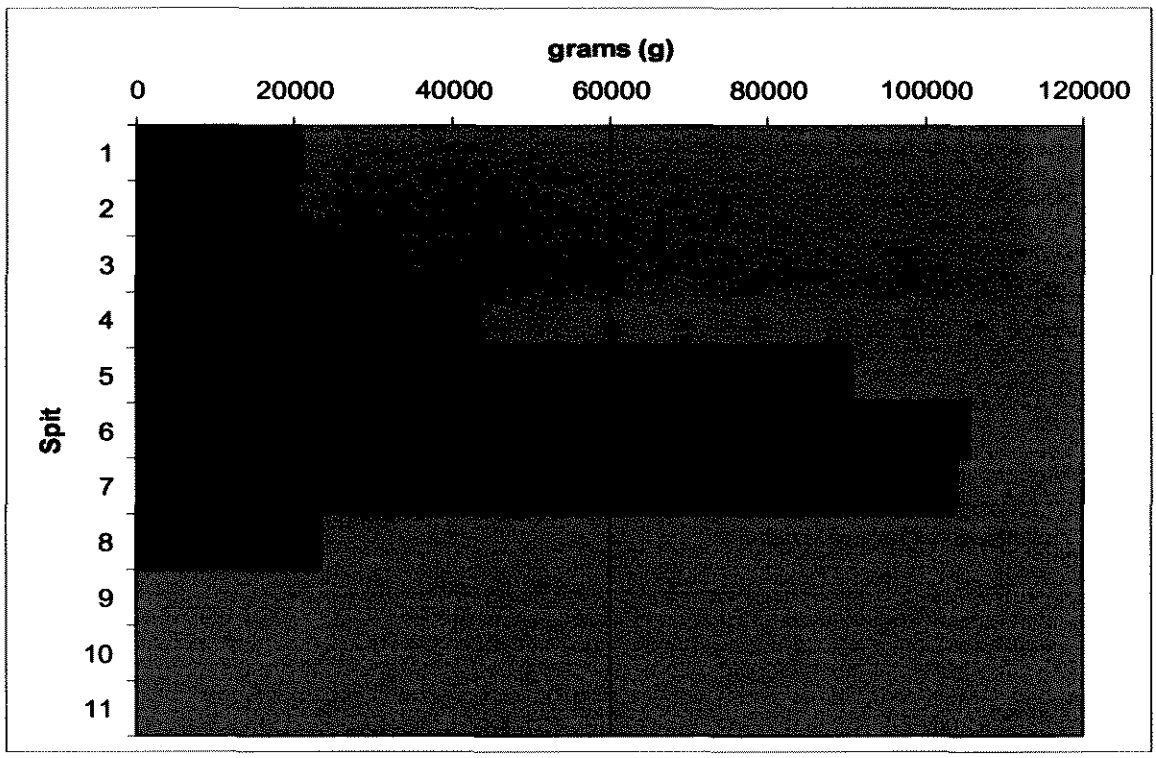

Figure 6.35: Discard of *Alathyria pertexta spp.* in grams per cubic metre by spit in GRE8 TP1, Riversleigh, northwest Queensland.

Fragmentation

The *Alathyria pertexta spp.* from GRE8 TP1 was quantified in terms of NISP and MNI. Due to large sample sizes, NISP has been calculated using a random 250 g sample, while MNI has been calculated based on 100% of the excavated material. Both NISP and MNI have then been extrapolated for a cubic metre of sediment. (Table 6.). Excluding spit 1 (where shell was exposed and recently trampled) NISP rises steadily until spits 4 and 2 where a higher level of fragmentation occurs. A similar trend for the older levels (phase B) is apparent in MNI. MNI from spit 9, rises significantly from spit 7 and 8 reaching approximately 2, 500 individuals/m^3 from spit 5 until the surface.

	Alathyria pertexta spp. abundance / m3	
Spit	NISP	MNI
1	25000	5100
2	8927	2339
3	4600	2420
4	8903	2629
5	4993	2424
6	5084	1088
7	2044	644
8	2091	600
9	1970	45

Table 6.16: NISP and MNI measures for GRE8 TP1, Riversleigh, northwest Queensland.

The ratio between NISP and MNI shows peaks in fragmentation in spits 1, 2 and 6, whilst spits 3 and 5 have much lower ratios than the mean of the deposit 3.42 (1 S.D.). The high level of fragmentation for spits 1 and 2 is due to small sample size and trampling. The peak in spit 6 (phase C) is interpreted as an indicator of greater levels in the intensity of site use at this time.

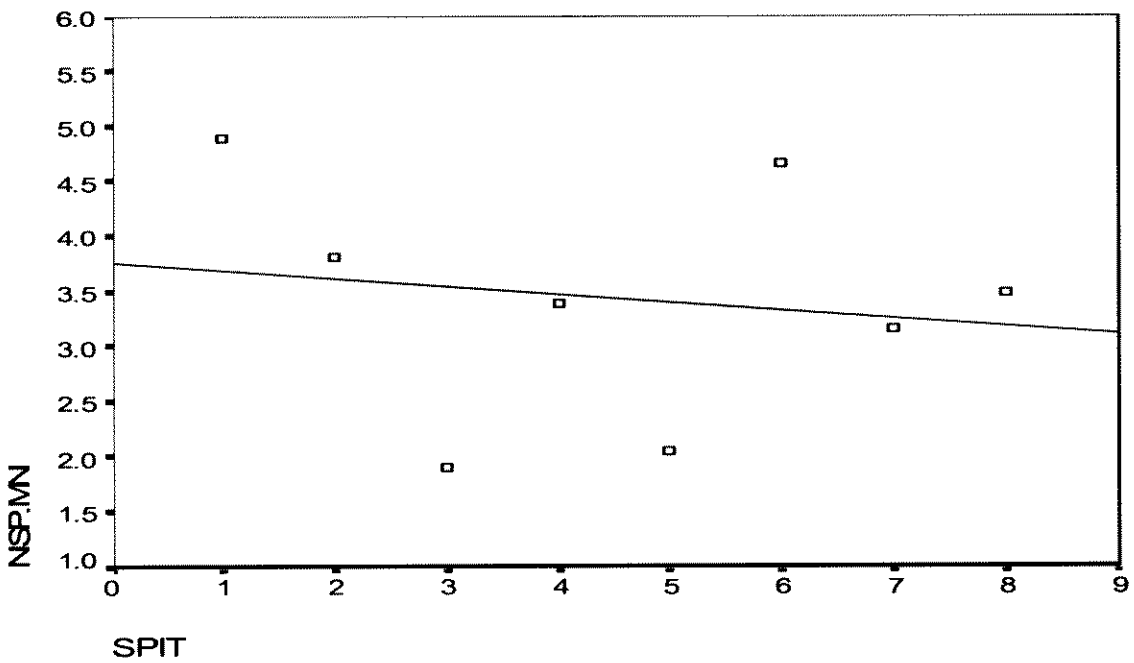

Figure 6.36: Ratio of NISP : MNI by spit for GRE8 TP1, Riversleigh, northwest Queensland.

MNI analysis

The total weight of *Alathyria pertexta spp.* for each spit was divided by the MNI for each spit (Figure 6.37). There is a linear relationship with a diminishing ratio through time in GRE8. Phases A, B, and C feature a high ratio of weight to MNI, whilst the later phases D, E and F are around half that of the early spits. This is a function of two features. First the lower, older shell is encrusted with calcium carbonate which increases the weight, and second fewer individuals occur in these levels compared to the upper spits. However, given the high rates of shell discard that occur throughout the middle and upper spits further metrical analysis of shell was undertaken to refine this linear relationship.

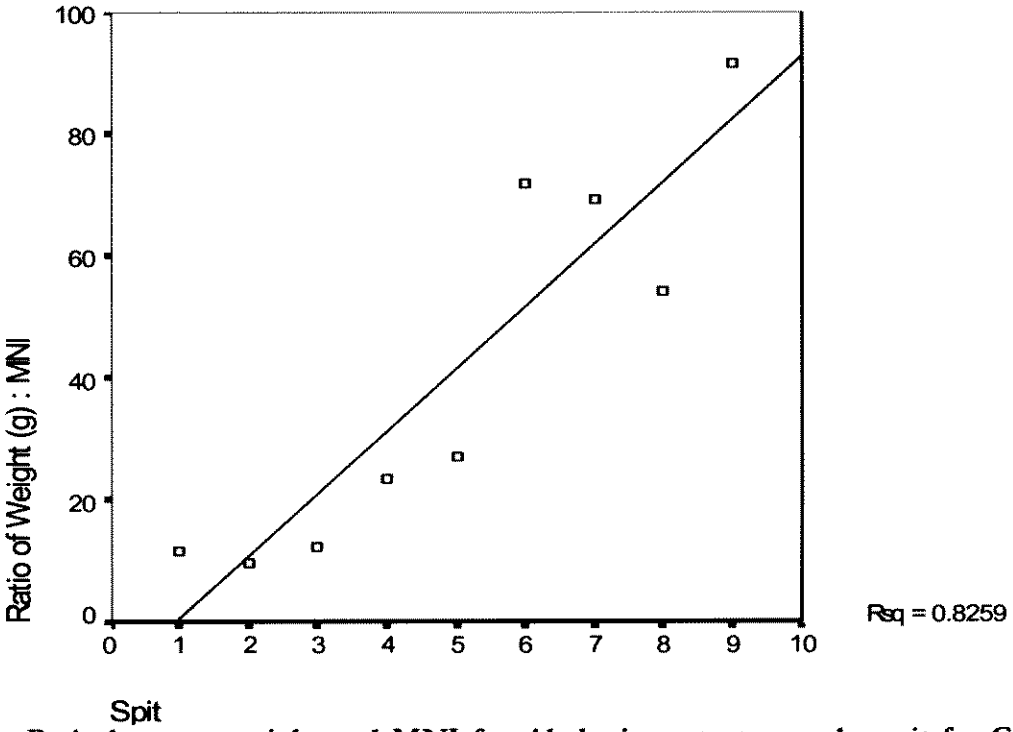

Figure 6.37: Ratio between weight and MNI for *Alathyria pertexta spp.* by spit for GRE8 TP1, Riversleigh, northwest Queensland.

Size analysis

Change in the mean valve size together with changes in species abundance provide a good indicator of the effects of human exploitation (see Spenneman 1989). The analysis is based on two assumptions: *(i)* the relative abundance of preferred shells will decrease through a midden deposit; and *(ii)* mean shell length will decrease from the bottom to top of the midden due to the effects of the exploitation (see Claasen 1998). People will select larger individuals within a population and reject those below a certain threshold. If the threshold for exploitation occurs at a size that is less than the size of the shell species at sexual maturity there will be risk that the population will be over-exploited. Other factors including environmental change may also affect species size, population structure and location.

The valve length of all complete *Alathyria pertexta spp.* individuals was recorded and mean length was plotted by excavation unit for GRE8 (Figure 6.38). A line of best fit shows a significant change in size through time, These results suggest over exploitation as a result of foraging behaviour during earlier phases B and C (30,000 Cal BP – 13,500 Cal BP).

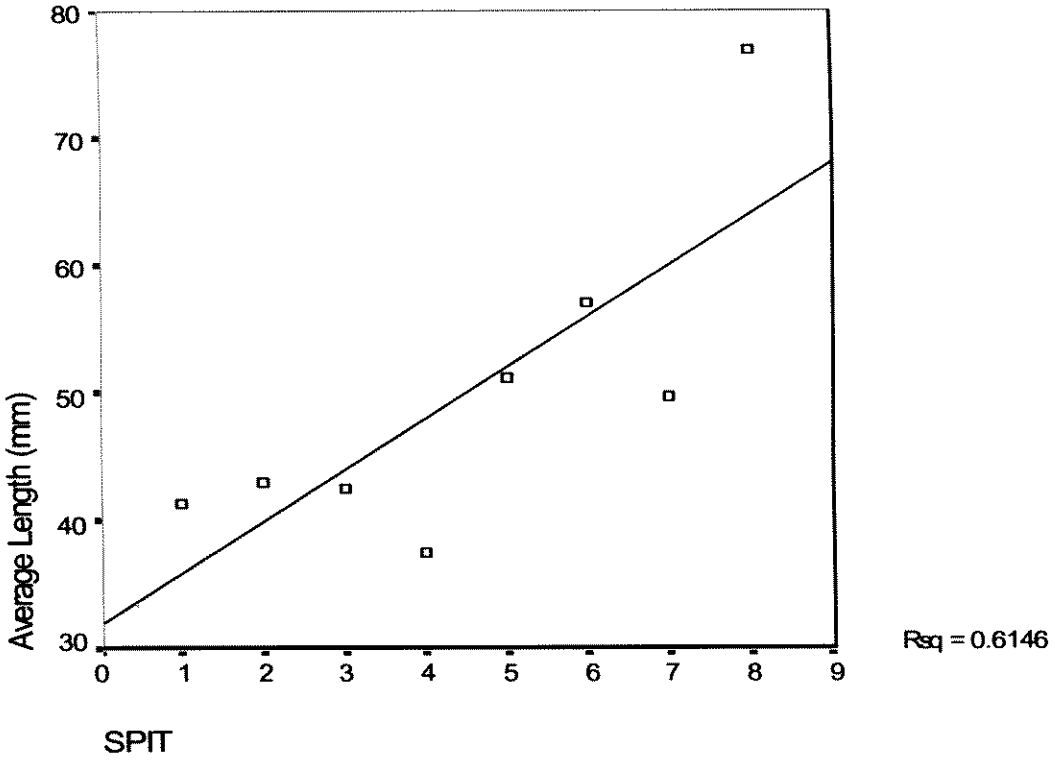

Figure 6.38: Mean length of *Alathyria pertexta spp.* by excavation unit for GRE8 TP1, Riversleigh, northwest Queensland.

Summary of GRE8

The GRE8 rockshelter was occupied from c. 37,000 years ago. During the following climatic phases the site appears to have either been continually occupied, or visited frequently until c. 4,000 years ago. Whilst sediment accumulation in the site is low during the LGM the increasing accumulation of midden deposit indicates persistent occupation of the shelter.

The TP1 excavation yielded almost 2,000 flaked stone artefacts. Whilst the assemblage is dominated by small chert flakes, significant changes occur through the sequence of occupation at GRE8. For example, there are important changes to reduction intensity and raw material procurement that occur at the end of phase B including the introduction of non-local stone. The appearance of greywacke just after the conclusion of the LGM is

consistent with Hiscock's conclusions for the Lawn Hill data where wider use of the landscape occurred in the post the LGM period. It is also at this time that seed grinding technology appears at GRE8, and stone artefact discard rates increase dramatically.

The faunal assemblage at GRE8 shows distinct relationships between resource exploitation, inferred through combination of lithic discard patterns and the food remains within the TP1 deposit. Until the conclusion of phase B and the wetter conditions of the post-glacial Late Pleistocene, evidence for hunting of terrestrial fauna is meager. After this point small mammals occur in steadily increasing numbers. During phases B and C, (30,000 and 10,000 Cal BP) high densities of *Alathyria pertexta spp.* and small amounts of turtle are found. After phases B and C, mussel shell accumulation is sustained though at a comparatively reduced level and consisting of smaller individuals. These trends appear to be consistent with a change in foraging strategies that includes a post glacial Pleistocene expansion of range and a reconfiguration in diet breadth.

The assemblages from GRE8 TP1 provide compelling evidence for the early occupation of northern Australia, in a location that might have provided a refuge corridor to the arid interior. The discard rates of flaked stone and shell indicate that the shelter provides compelling evidence for a persistent occupation of the Gregory River corridor during the Late Pleistocene.

6.4 Riversleigh - Sites Distant to Permanent Water

The archaeological record at three sites located in different patches and at variable distances to permanent water in the Riversleigh area of the research region has provided further insights into the prehistory of this region. These sites consist of two small rockshelters located near intermittent and ephemeral water sources and a large cavern complex located over 5 km from water.

6.4.1 LH23

LH23 (Verdon Creek shelter) was first recorded during the 2002 rock art surveys. The site was excavated during the 2003 field season and in 2004, Amy Stevens completed analysis of the assemblage of the site for a BA (hons) thesis (Stevens 2004). Consequently this site is reported only briefly here, in the context of its position in regional settlement and subsistence patterns.

Site Setting

LH23 is located on Verdon Creek in the Riversleigh region. Verdon Creek is an ephemeral watercourse terminating at the Gregory River, approximately 3 km beyond the confluence with the O'Shannassy River at Riversleigh. The site is approximately 7 km northwest of the Gregory River, the closest permanent fresh water. LH23 is located approximately 30 m from the southern bank of Verdon Creek, and within 100 m of the commencement of the Riversleigh limestone plateau. No other sites have been recorded within this area, and the closest location with evidence of visitation is about 1 km further west along Verdon Creek; a small art site.

Vegetation in the vicinity of LH23 is comprised of dominant local woodlands and grasslands associated with the adjacent limestone talus slope. Riparian fringing communities occur up to 15 m from the edge of Verdon Creek.

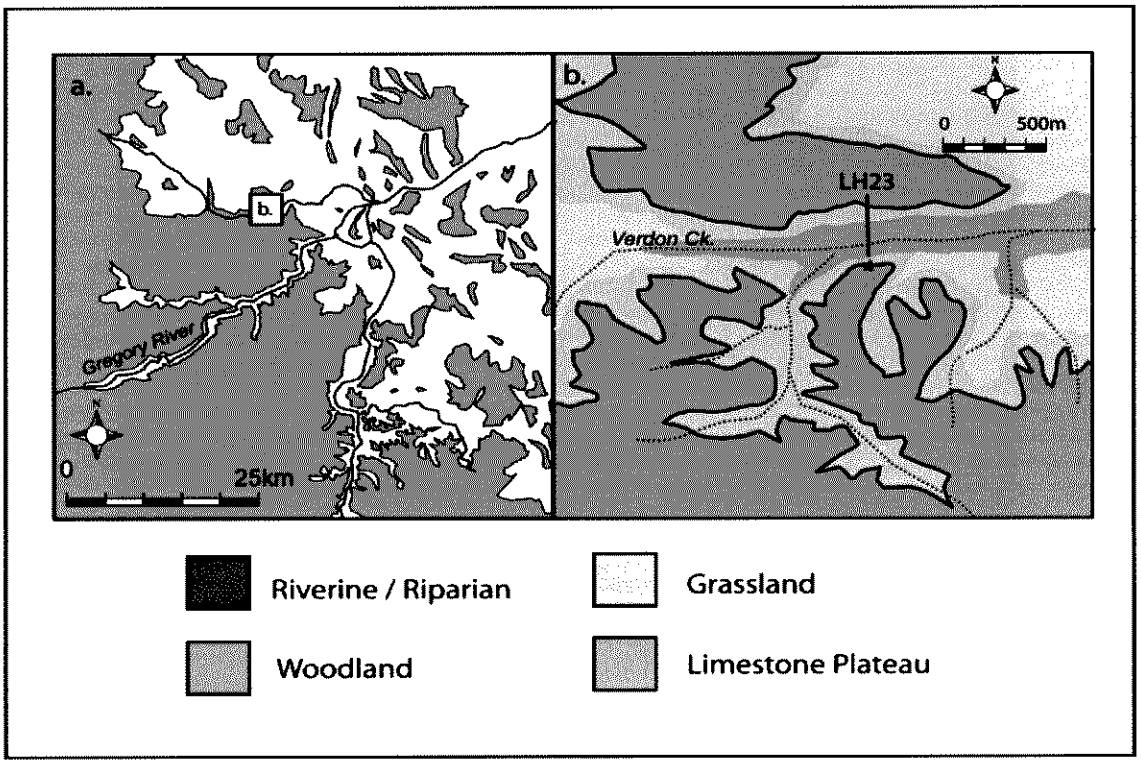

Figure 6.39: Location of LH23 (Verdon Creek site), Riversleigh northwest Queensland. A. shows the general location of the area marked as b. B. shows the location of LH23 and relationship to local patch types.

Site Description

LH23 is a small limestone rockshelter, c. 6 m deep, 4 m wide at the entrance, and 2 m in height. A series of large boulders of up to 2 m in diameter that have fallen from the plateau above and now rest at the entrance of the rockshelter, acting as sediment traps. The surface of the LH23 features sandy unconsolidated sediments and large boulders. At the rear of the site the wall terminates at a stone floor. No flaked stone artefacts have been observed on the surface of the rockshelter. However, many artefacts occur outside the shelter and extend down the talus slope. The shelter has two images near the entrance consisting of a monochrome snake and an emu track.

Figure 6.40: LH23 rockshelter site, Verdon Creek, Riversleigh, northwest Queensland.

Excavation and sampling

In 2002, a 50 cm x 50 cm testpit was excavated within the LH23 shelter. Excavation consisted of seven 5 cm spits to a maximum depth of 26 cm below the surface, where excavation terminated on a large sandstone slab, possibly of roof fall. All excavated sediment was weighed, recorded and sieved through 4 mm and 2 mm mesh on site.

In addition to the excavation of the LH23 shelter an extensive surface collection of flaked stone was made along a transect between Verdon Creek and the shelter. This collection consisted of 1 m x 1 m squares placed at 5 m intervals (a total of six collection squares). The fringing woodlands, grasslands and the scree slope in front of the site were sampled in this transect.

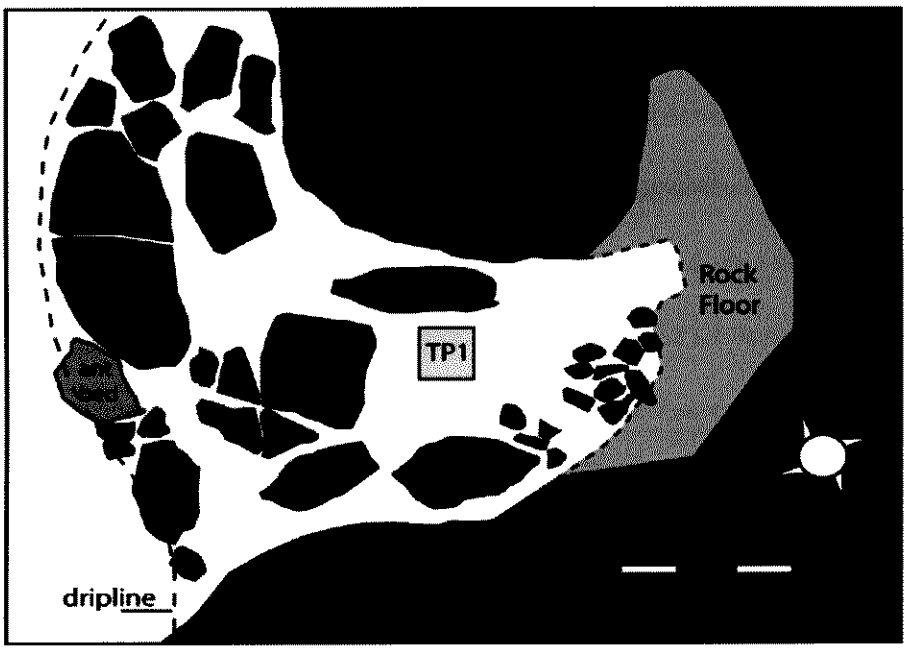

Figure 6.41: Site plan of LH23 rockshelter indicating the position of the excavated square, Verdon Creek, Riversleigh, northwest Queensland.

Stratigraphy

The LH23 deposit consists of two stratigraphic units terminating on limestone bedrock/roof fall at 26 cm below the surface. Unit A (10 – 26 cm depth) is comprised of dark grey silt with pieces of limestone rubble. Unit B consists of the upper 10 cm of deposit and consists of loose grey/brown silty sediment (Figure 6.42).

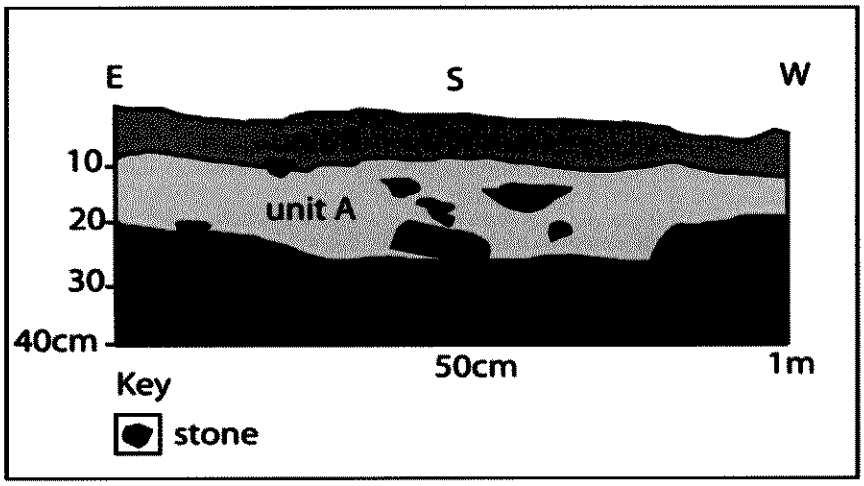

Figure 6.42: Stratigraphic profile of the LH23 deposit, Riversleigh.

Chronology

Three charcoal samples from the LH23 deposit were submitted for radiocarbon dating. The material selected for dating was collected from the 2 mm sieve fraction of spits 2, 4, and 7, representing the upper, middle and basal layers of the deposit (Table 6.17). Results of this analysis show that LH23 was first occupied in the very recent past c. 1729 AD (2-sigma range) and last occupied around 1824 AD. The LH23 sediments have accumulated quickly, but at a differential rate of about 27 cm per 100 years. The age-depth curve shows that the lower Unit A sediments accumulated at a much faster rate than those of Unit B (Figure 6.43).

Spit	lab id	material	Raw date	error	calib lower	calib upper	mean
2	OZH283	charcoal	110	35	256	modern	128
4	Beta-193703	charcoal	190	40	292	modern	146
7	Wk-13560	charcoal	264	40	442	modern	221

Table 6.17: Radiocarbon determinations for LH23 rockshelter, Verdon Creek, northwest Queensland.

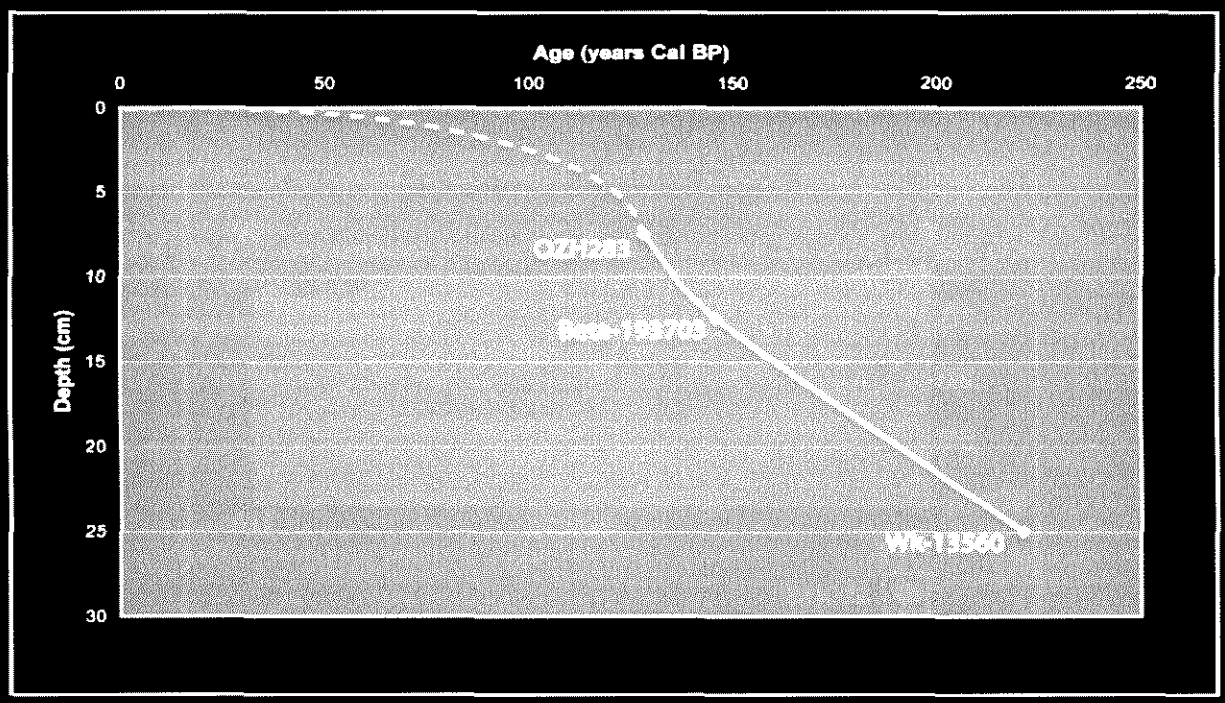

Figure 6.43: Age-Depth curve for LH23 TP1, Verdon Creek, northwest Queensland.

Flaked Stone Assemblage

Stevens analysis of the LH23 flaked stone assemblage examined 510 artefacts: 330 flakes, 17 retouched flakes (including 5 backed artefacts), 4 cores, 114 flake fragments, and 45 flaked pieces. After removal of non diagnostic stone the total sample size is 351 artefacts (excluding fragments and pieces) (Table 6.18).

	Flakes		Retouched Flakes		Cores	
	No.	%	No.	%	No.	%
Total Assemblage n = 351	330	94.1	17	4.8	4	1.1

Table 6.18: Abundance and frequency of flaked stone in the LH23 assemblage Verdon Creek, northwest Queensland.

Whilst there is no clear relationship in discard over the occupational history of the shelter, the highest rates of discard occur in the lowest spit 7 (Figure 6.44), suggesting that perhaps the occupation sequence may be deeper than the basal excavation levels in the trench. As with the GRE8 site, the LH23 assemblage is dominated by local chert most likely sourced as cobbles from Verdon Creek. Small amounts of greywacke, silcrete and quartzite also occur in the deposit.

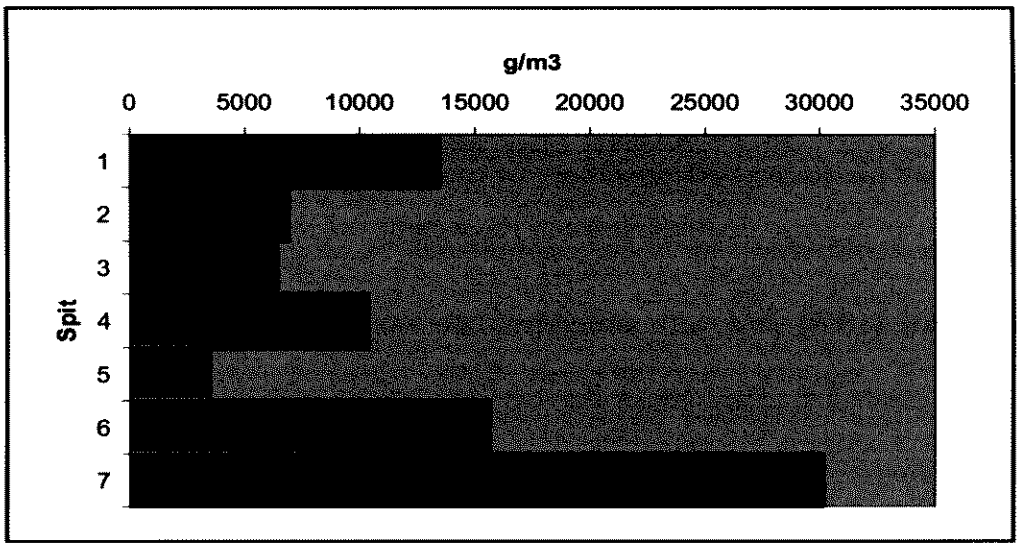

Figure 6.44: Artefactual stone by weight and spit for TP1 at the LH23 rockshelter, Verdon Creek, northwest Queensland.

Breakage

Flake breakage at LH23 is dominated by transverse breaks which account for 15-40% of the total assemblage. Longitudinally broken flakes comprise less than 2% of all broken flakes. Breakage is most likely the result of a combination of high levels of heat fracture and trampling.

%	Spit						
	1	**2**	**3**	**4**	**5**	**6**	**7**
% flakes broken	14.3	15	29.4	13.7	10	39.3	13.4
% proximal fragments	0	4.7	12.3	6.1	3.1	11	3.9
% of medial fragments	0	0	0	0	3	0	0
% distal fragments	11.1	10.3	17.1	5.6	6	27.1	8.1
% longitudinally cone split	3.2	0	0	2.0	0	1.2	1.4

Table 6.19: Flake breakage in LH23 TP1, Verdon Creek, northwest Queensland. (n=330)

All flakes in the assemblage were produced using direct percussion, with bipolar flaking only identified on retouched flakes. The majority of complete flakes (between 78 - 90%) have less than 25% cortex on their dorsal surfaces, though there is slightly more variation in the lowest spits than in upper spits.

The LH23 flaked stone assemblage is dominated by small flakes (62% are less than 2 cm^2 in area) with small platforms. No instances of multiple flake, crushed, or faceted platforms were documented with the assemblage dominated by single flake scar (82%). Cortical platform surfaces (13%) and with indeterminate surfaces (5%) forming the remainder. Platform thickness and area are generally very small (50% with platforms < 20 mm^2). The occurrence of aberrant terminations accounts for 21% of the assemblage indicating a similar level of expertise in knapping to other sites in the region.

Retouched Artefacts

Of the 17 retouched artefacts, 11 are amorphously retouched flakes, 1 is a broken unifacial point and 5 are backed artefacts. Amorphous flakes featured non-invasive retouch of the distal end and/or one margin. The number of retouch scars on these artefacts ranged between 1 and 5.

Usewear study of the retouched assemblage concluded that all artefacts had evidence of use (R. Fullagar pers. comm. 2007). The backed artefacts featured rounding, smoothing or polish and most featured wear marks on the chord and other indicators of hafting of the backed edge. One example (LH23-6-141) featured usewear consistent with cutting of soft fibrous material.

Fauna

The faunal assemblage at LH23 is primarily mammal bone and is dominated by small and micro mammals (particularly rodents) (Figure 6.45). Macropods and large to medium mammals also occur in small amounts, the most frequently identified being *Lagorchestes conspicillatus* (spectacled hare wallaby). There are also low numbers of small reptiles (see Stevens 2004:98-99). Stevens considers that the majority of this assemblage has been created by carnivores (most likely *Tyto alba* the barn owl), with the larger mammal remains brought into the rockshelter by humans (Stevens 2004:99). It also seems likely that some macropod remains in the shelter resulted from natural death.

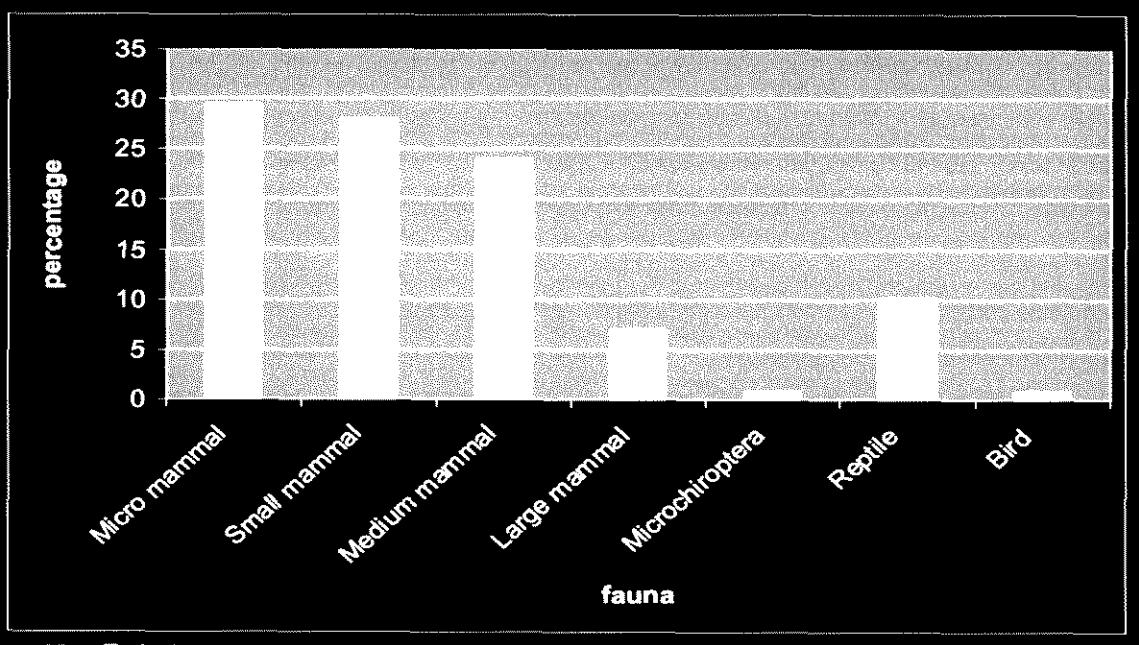

Figure 6.45: Relative percentages of different faunal classes at LH23, Verdon Creek, northwest Queensland.

Summary

The distance from permanent water and the nature of the lithic assemblage at LH23 indicates that it was a seasonally occupied shelter, visited during periods of high rainfall when Verdon Creek flowed. The site probably constitutes a short term residential base at a time when population pressure along permanent water at the Gregory River (Stevens 2004:114) resulted in increased mobility to include areas away from permanent water. The lithic assemblage supports use of the site as a temporary hunting base where reduction sequences indicate a focus on tool maintenance.

6.4.2 The Grotto (GRE13)

This site is known locally as 'The Grotto' due its location at the edge of a breakaway of the limestone plateau, which features many impressive 'muffin' shaped mesas up to 15 m in height creating a maze of small pathways. The 'Grotto' is well known to locals and for most of the last 10 years has also been visited by tour groups. The area surrounding and including GRE13 is important to the Aboriginal community and knowledge of the location and significance of the site are restricted. In recent years the Aboriginal community have successfully halted tourist visitation of the area and have protected the GRE13 site from cattle through erection of fences. Although the GRE13 rockshelter has been visited in the past, its location approximately 300 m east of the main 'Grotto' location has ensured that it is not known to tourists and is subsequently in good condition.

The Aboriginal community is very protective of the meaning and significance of the GRE13 site. The site is designated as a men's site and is secret in nature.

Site Setting

GRE13 is located at the junction of the Riversleigh region limestone plateau and grasslands patches (Figure 6.46). The site is on the blacksoil plain c. 300 m from the commencement of the plateau proper. The local vegetation consists of grasses dominated by *Triodia spp.* with few trees. Grasses are sparse due to extremely poor soil quality and the presence of dense chert/limestone rubble.

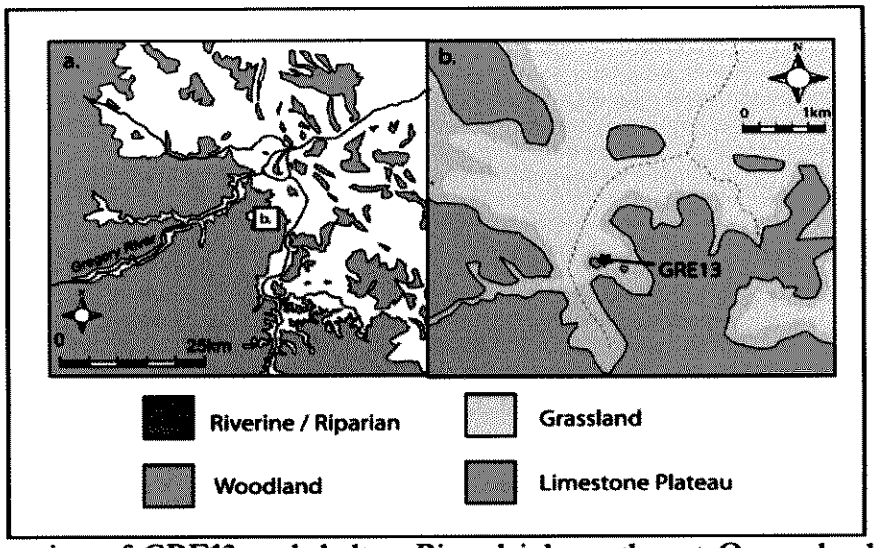

Figure 6.46: Location of GRE13 rockshelter, Riversleigh northwest Queensland. A. shows the general location of the area marked as b. B. details the location of GRE13 and its relationship to local patch types

A small intermittent drainage channel lies approximately 100 m to the north of GRE13. Water flow along this channel derives from wet season runoff passing through the 'Grotto' formation towards the northeast and blacksoil plain. Once on the plain this channel links to other channels that eventually terminate into the O'Shannassy River. The O'Shannassy River is the closest permanent water to GRE13 and is approximately 2 km east of the site.

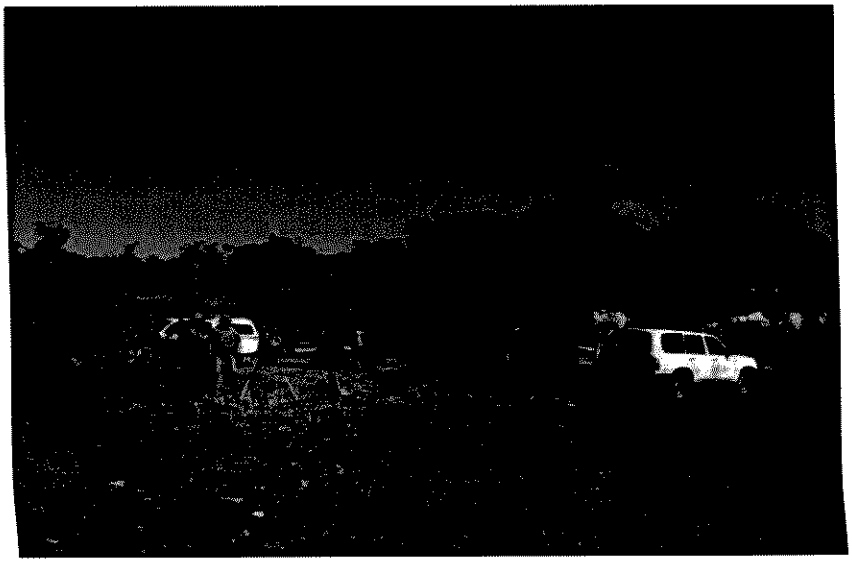

Figure 6.47: Excavations in progress at GRE13 (the Grotto) rockshelter, Riversleigh, northwest Queensland.

Site Description

GRE13 is a small limestone rockshelter located on the most prominent of the numerous local limestone plateau outliers. The GRE13 outlier is approximately 750 m^2 in area and c. 10 m in height. GRE13 is on the southeastern side of the outlier, and is a long thin cave created by water flow through rock. The entrance to the shelter is approximately 4.5 m wide and 2 m in height. The cave forms a long tunnel that terminates as a small chamber 10 m from the entrance. The exterior of the breakaway features numerous chert nodules, many of which appear to have been flaked.

The interior walls of GRE13 are almost vertical and extend generally to a height of between 1.5 - 2 m from the floor surface (Figure 6.48). The northern wall features an extensive panel of painted and drawn bichrome rock art. The floor surface of GRE13 consists of unconsolidated sandy sediment and covers an area of approximately 18 m^2. At the time of excavation, the surface of the site was littered with 15 roughly formed timber posts that were likely to have been used as platforms for storage of European goods by the managers of the local Riversleigh station during World War 2. The surface of the shelter featured a few stone artefacts; however numerous flaked artefacts were noted in the local area around the entrance of the site.

Figure 6.48: Interior of GRE13, Riversleigh showing excavations in progress, Riversleigh, northwest Queensland.

Excavation

A 1 m² testpit was excavated within the shelter located where the deposit was though to be deepest. Excavation was undertaken in 5 cm spits within stratigraphic units and all material was weighed, sieved and sorted on site. The excavation terminated at a depth of 30 cm within a rubble and limestone bedrock matrix. All material recovered was sieved through 4 mm and 2 mm paired mesh and anything greater than 4 mm in size was sorted by hand on site.

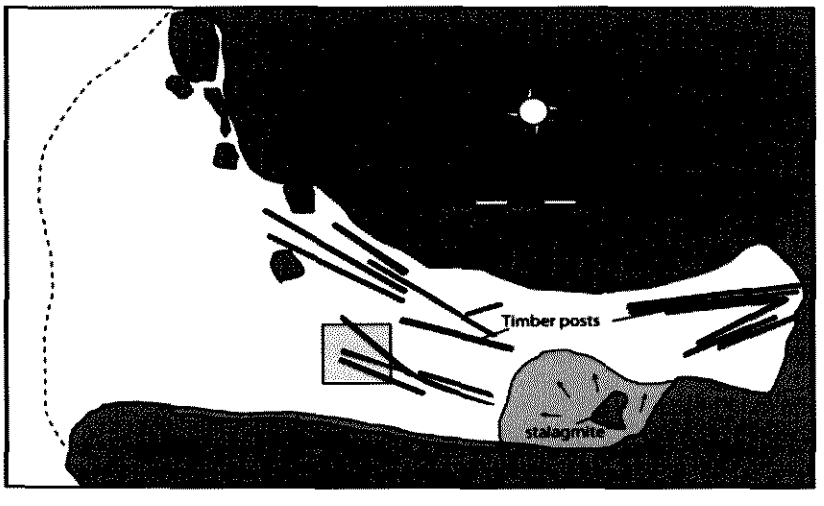

Figure 6.49: Plan of GRE13, Riversleigh showing location of excavation square, rock art and timber posts.

Stratigraphy

The stratigraphic sequence at GRE13 consists of four units and terminates on fragmented limestone bedrock 30 cm below the surface. Unit A is the lowest horizon (22 - 30 cm) and consists of orange/brown soils and gravel and feature a low density of flaked stone material. Unit B (15 - 22 cm) consists of a dark grey brown colour and feature high levels of charcoal, ash and cultural material. Unit C (11 - 15 cm) is a lighter brown soil with a heavy concentration of ash and flaked stone. Unit D (1 - 11cm) is loose dark brown soil featuring low densities of charcoal and flaked stone (Figure 6.50).

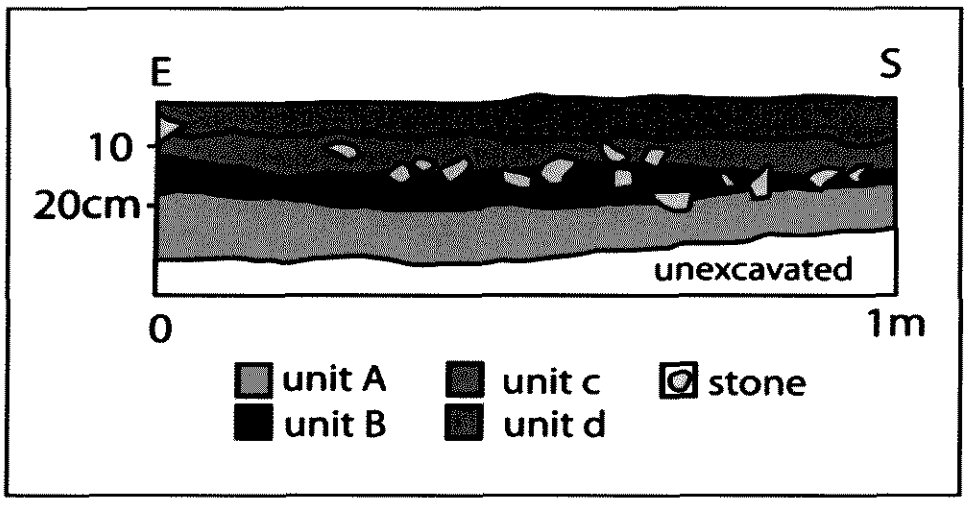

Figure 6.50: Section profile of TP1 at GRE13, Riversleigh, northwest Queensland.

Chronology

A single charcoal sample from GRE13 was submitted for radiocarbon analysis consisting of a large single fragment of charcoal recovered *in situ* during excavation in spit 6 (27 cm depth). The radiocarbon determination has been calibrated using the Calib radiocarbon program and expressed to a two sigma range (Table 6.20). The mean of this range is 607 cal BP. The upper spits of the site are considered to be approximately 100 years old due to the presence of an early 20th century metal button in spit 2.

Spit	Depth (cm)	Sample weight (g)	Laboratory Number	dC13	Radiocarbon Age (yr BP)	Calibrated Age (yr cal BP)
6	27	12	Wk-13559	-8.4 ± 0.2	796 ± 41	657.5

Table 6.20: Radiocarbon determination and calibration for charcoal from GRE13 TP1, Riversleigh, northwest Queensland.

It is possible that the basal charcoal sample used for dating may have migrated a few centimetres deeper in the unconsolidated Unit A sediments through the rubble matrix and that basal date is best used to describe the junction of the Unit A and B sediments. It is likely that much of the material that is present in Unit A originates from Unit B and marks the first use of the site about 600 years ago.

Flaked Stone Analysis

The GRE13 flaked stone assemblage consists of 440 artefacts, including an MNF of 403 unmodified flakes (91.6%), 13 cores (2.9%) and 24 retouched artefacts (5.45%). The dominant stone raw material is chert which is present as nodules on the mesa formations that surround the site. It accounts for 96.6% of the assemblage (n=425) whilst the remaining raw materials consist of 7 silcrete flakes (1.6%), 3 limestone flakes (0.7%), 2 greywacke flakes (0.45%), and 1 flake each of quartz, and quartzite. The rates of discard are low in the lower spits, peak in the middle sediments before reducing in the upper spits (Figure 6.51).

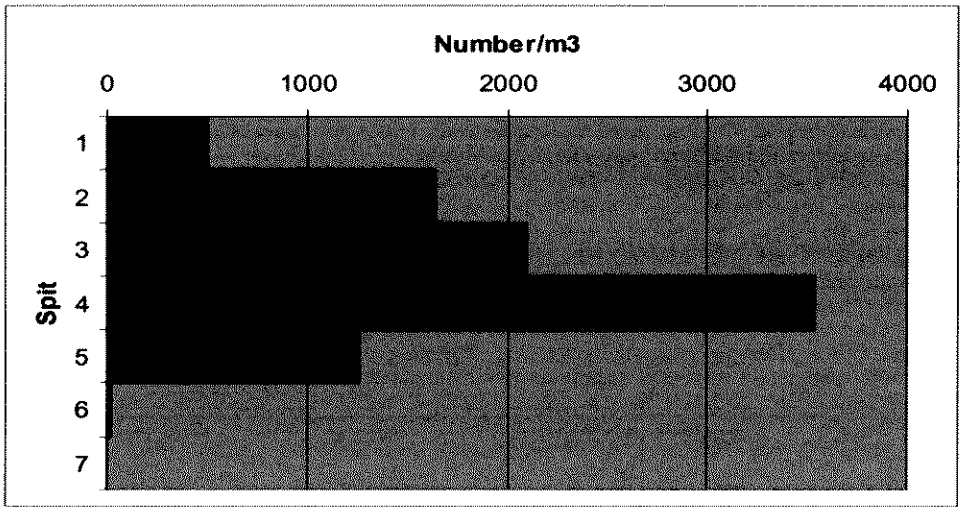

Figure 6.51: Discard of flaked stone artefacts by minimum number of artefacts (MNI)/m³ for GRE13, Riversleigh, northwest Queensland.

Flaked Stone Reduction

Flaked stone reduction has been measured by the percentage of dorsal cortex and documentation of platform features. These measures indicate that the flaked stone assemblage is highly reduced. Seventy three percent of all flakes have less than 25% cortex, 22% of all flakes feature overhang removal scars on the dorsal margin of the flake platform, and platforms are dominated by single flake scars (84.6% n=270) and cortical surfaces (5.6% n=18).

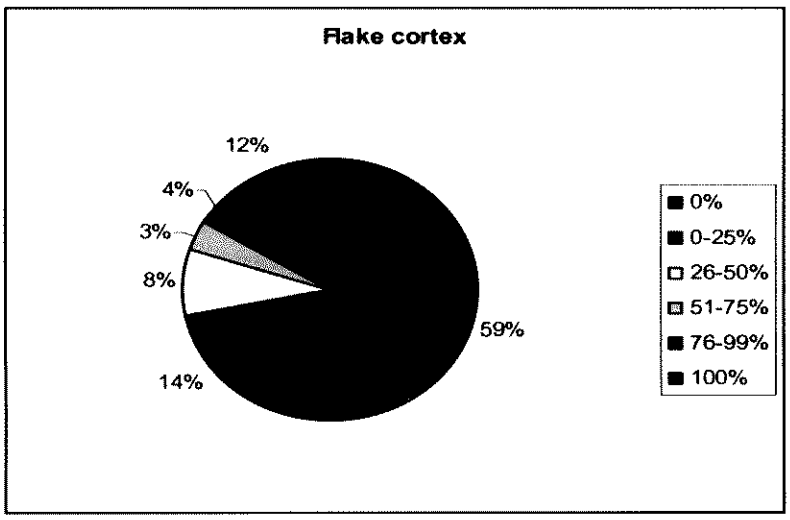

Figure 6.52: Relative percentages of different cortical classes for flakes at GRE13, Riversleigh.

These results are consistent with the size of flakes, the mean axial percussion length of flakes at GRE13 is just 18.8 mm and the mean width at midpoint is 15.1 mm (standard deviation is 9.05 and 6.7 respectively) (Figure 6.53).

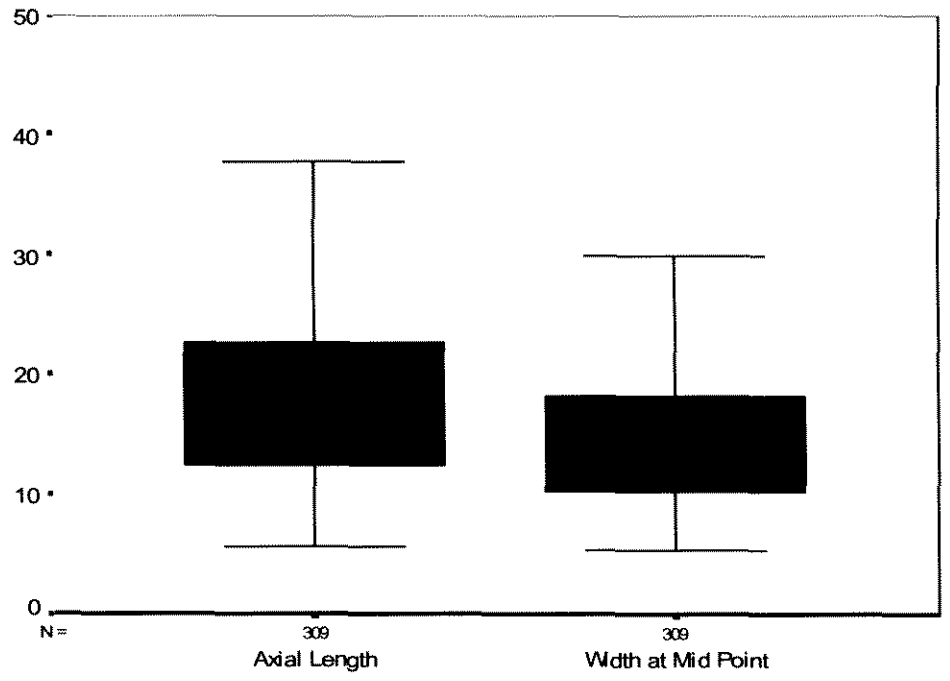

Figure 6.53: Box plot of the mean, mode and range of axial length and width at mid-point of flakes in GRE13 TP1, Riversleigh, northwest Queensland.

Core Reduction

Thirteen cores were recovered from spits 2, 3 and 4 with most occurring in spit 4 (n=8). All of the cores were manufactured from chert except for a large split quartzite cobble with over 80% cortical coverage. Most of the cores had only one platform (n=8) however up to three platforms were noted on the remainder. After removing two heavy outliers the mean weight of the assemblage was 27.54 g (SD = 14 g), average block size was 24.95 cm^3 (SD = 10.57 cm^3) and the average length of longest scar present was 22.5 (SD = 4.08 mm).

Faunal Assemblage

The faunal assemblage from GRE13 TP1 consists of few terrestrial faunal remains and is very fragmented. Small to medium mammals, and in particular wallaby are the most abundant fauna, with lesser amounts of large macropod and small mammals. Most faunal discard occurs in spits 4 and 5 of the deposit (Table 6.).

Taxon	Spit						Total
	1	2	3	4	5	6	
Macropod - kangaroo	2	2					**4**
Macropod-wallaby		2	2	2	4		**10**
Medium mammals				1			**1**
Small/medium mammals				1	7		**8**
Small mammals			4	1			**5**
Avis (bird)		1		1			**2**
Total	**2**	**5**	**6**	**6**	**11**	**0**	**30**

Table 6.21: NISP of faunal material from GRE13 TP1, Riversleigh, northwest Queensland.

Alathyria pertexta spp. occurs only in small amounts in the deposit, peaking in spits 4 and 5 with 45.4 g and 30.6 g discarded. Although only a fraction of material was recovered from excavations it indicates that exploitation of permanent water sources that are over 5 km distant brought material to this location.

Summary

GRE13 is located in a marginal resource patch at the junction of plateau and blacksoil plains. Most of the time the site is at least 5 km from the permanent water and only after very heavy rainfall would ephemeral pools of water result in the area. These factors combined to result in occupation of this rockshelter occurring very late in the human record for the region. People used the Grotto for the consumption of meals and as a

location to carry out basic maintenance of flaked stone tools. Much of the chert present in the assemblage probably originates from cobbles along either the Gregory or O'Shannassy Rivers. Over the last 600 years patterns of Aboriginal occupation are consistent with a temporary logistical or residential site for a few people for short periods of time.

Contemporary Aboriginal knowledge of the Grotto relate to its use solely as an initiation site. This recent view of this locality appears to complement the archaeology. Aboriginal people claim that during such activities the site was used as a residential base for just a few individuals who had few material requirements while residing there.

6.4.3 Gamanyi

Gamanyi was first located and explored in the 1980s by paleontologists from the University of New South Wales. At this time at least two test pits were dug to investigate questions regarding faunal succession during the Late Quaternary. The site was named 'Carrington's Cave' after a helicopter pilot involved in the first trips to site. During 2002, the site was re-visited by Aboriginal elders and myself and a new indigenous name 'Gamanyi' was bestowed in reference to the bush lemon tree which grew at the entrance. Gamanyi is well known to the Aboriginal community and is considered a ceremonial secret men's site. During the 1980s there was widespread discussion between the paleontologists, Queensland Parks and Wildlife Service and the Waanyi people regarding the significance of the site and the issue of excavations. During 2002 fieldwork the Aboriginal community provided permission for future excavation at Gamanyi. Due to logistical complexities Gamanyi was excavated the following year in 2003.

Site Setting

Gamanyi is located within the limestone plateau in the Riversleigh World Heritage Area of Lawn Hill National Park. The site is adjacent to the upper reaches of an unnamed gorge which extends to Ixion Creek, a semi permanent water course. The nearest reliable permanent water to Gamanyi is located in the Gregory River and is approximately 5 km distant. This distance is intensified by the nature of the gorge system that must be traversed to access Gamanyi. A one way trip to the river would take between 2 - 3 hours across sharp karren limestone.

The local landscape surrounding Gamanyi is comprised solely of limestone plateau and skeletal soils supporting a meager vegetation community. The vegetation community near the site consists of spinifex, grasses, and scattered eucalypts plus the small native lemon tree at the entrance to the site. During excavation in 2003 the only fauna observed at the site were the numerous bats that inhabited the caves. A variety of small to medium mammal species and reptiles are known to inhabit the plateau in this locale.

Site Description

The Gamanyi site is a series of doline caves, which were created by fluvial erosion of large cavern areas within the limestone. The area surrounding Gamanyi features the remains of what would have constituted a front chamber of the site that has collapsed and now resembles a flat sandy gully between the original walls of the chamber (Figure 6.54).

Figure 6.54: The Gamanyi entrance and the now collapsed front chamber, Riversleigh, northwest Queensland.

The remaining caverns of Gamanyi consists of a massive complex that extend over 300 m from the entrance. They are approximately 20 m below the surface and up to 50 m in width. There are two primary chambers to the site. The front chamber is located down a 10 m scree slope and is approximately 40 m x 30 m x 3 m in dimension. The first 10 m at the front of this chamber receives only dappled sunlight and features stone arrangements. At the rear of the chamber is a massive guano pile approximately 10 m x 20 m x 1 m. The rear chamber is linked to the front by a tunnel that is 30 m x 1.5 m x 2 m and drops approximately 10 m from front to back. The rear chamber is 60 m x 50 m and up to 30 m in ceiling height. The ceiling of the chamber has cracks and holes that extend to the surface, and are now filled with rocks, but may have acted as pit traps sometime in the past. It is in this rear chamber that paleontologists have previously excavated two trenches (Figure 6.55).

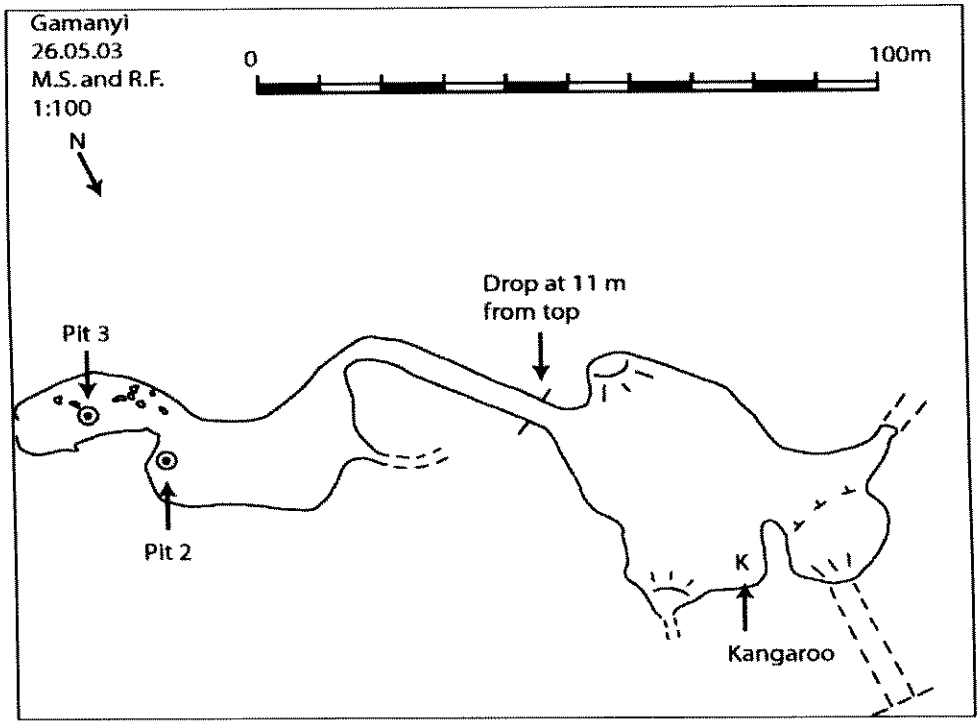

Figure 6.55: Plan of Gamanyi showing the two main chambers and the locations of excavations (pit 2 and 3) within the cave, Riversleigh, northwest Queensland.

Excavation

Excavations at the Gamanyi site consisted of three 50 cm x 50 cm test pits. Pits 1, 2 and 3 were placed where there was the greatest chance of sampling a cultural sequence and where they did not affect important site features. Pit 3 was located at the front of the first chamber; Pit 1 in the area of the front chamber that featured deep sediment and no visible disturbance; whilst Pit 2 was placed outside the shelter in deep sandy sediment (Figure 6.56). Due to logistical complexities (lighting, power and safety issues) the rear chamber was not excavated.

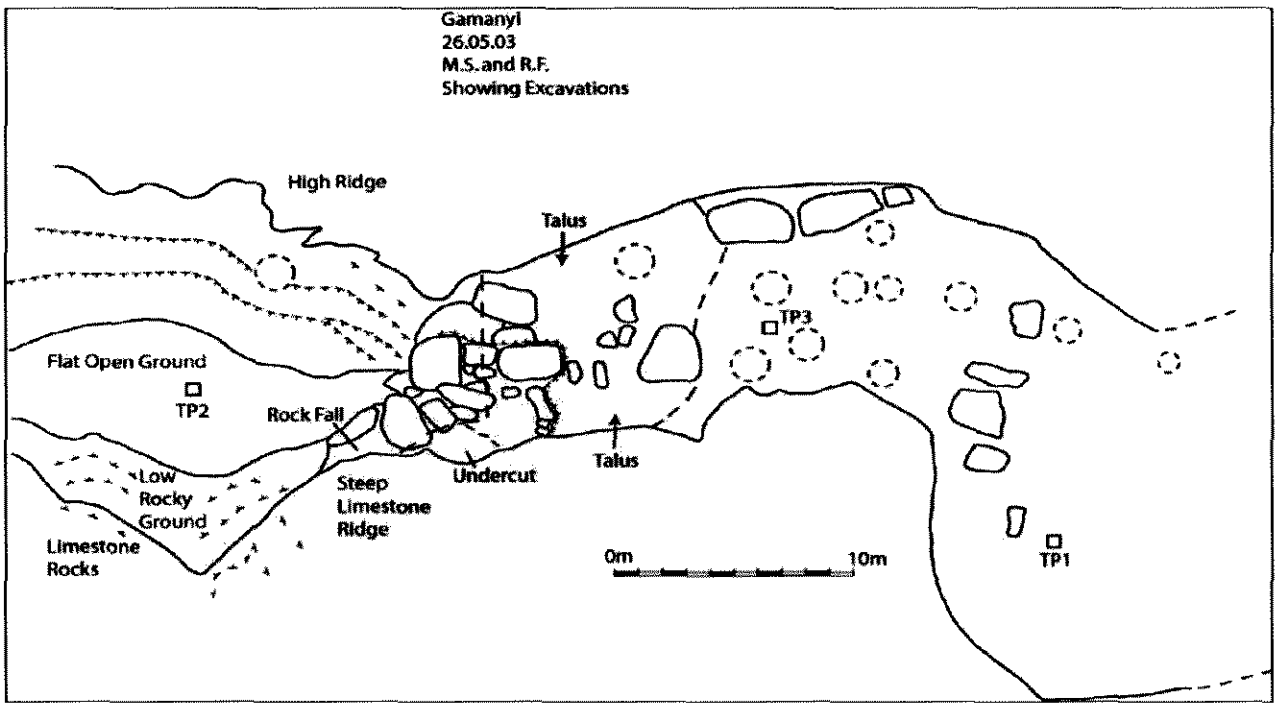

Figure 6.56: Plan of first chamber at Gamanyi showing location of excavated trenches, Riversleigh, northwest Queensland.

All three test pits were 50 cm x 50 cm and were excavated in 5 cm spits within stratigraphic units. The two trenches located inside the cavern were problematic to excavate as they featured roof fall, large flow stone, loose sediment and considerable bioturbation due to invertebrates. The trenches were excavated until large boulders were encountered between 20 and 49 cm below surface level. Pit 2, located outside the cavern, was excavated to a depth of 38 cm below the surface at which point a heavy rubble matrix was encountered.

Stratigraphy

The stratigraphy of both the trenches excavated within the Gamanyi cave was very similar, and consisted of a single unit of unconsolidated very fine brown sediment, to a depth of 22 cm below surface in testpit 1, and to 28 cm in test pit 3. At 22 cm in testpit 1 a large piece of roof fall was encountered that precluded further excavation. In testpit 3 excavation proceeded to until 49 cm depth. Within testpit 3 a change to red/orange sediment was noted below c. 27 cm depth. Excavation of testpit 3 concluded at a depth of 49 cm below

the surface, when numerous large slabs of limestone protruded from the sections of the trench and no further control to excavation was possible. The red/orange sediments present in this trench have the same composition as the grey sediment that overly them, but have been exposed to a long period of *in situ* weathering. Testpit 2, located outside the cavern featured a very different stratigraphy to testpits 1 and 3. It consisted of homogenous brown dry sediment with particles of charcoal throughout.

Chronology

Three radiocarbon determinations were obtained for the test pits at Gamanyi. Two determinations were obtained for testpit 2 and 1 from the basal spit of testpit 3. These dates correspond to the levels in each trench where lowest artefacts were recovered. Occupation of Gamanyi commenced c. 1,000 BP.

id	lab id	material	Raw date	error	calib lower	calib upper	Calibrated mean (2 sd)
TP2 Sp2-1	OZH615	charcoal	460	50	325	539	432
TP2 Sp6-1	OZH616	charcoal	1150	50	924	1168	1046
TP3 Sp8	OZH608	charcoal	1010	40	789	955	872

Table 6.22: Radiocarbon determinations for the Gamanyi site, Riversleigh, northwest Queensland.

Assemblage

The flaked stone, charcoal, bone and shell assemblages from all three trenches indicate human use of the site in the recent past. The archaeology consists of a small quantity of

flaked stone artefacts (1 artefact in test pit 1, 35 in testpit 2, and 24 in testpit 3). All artefacts are small, chert unmodified and broken flakes. Most material was found to occur outside the cave (Table 6.3). Due to small sample size, no further analysis of this material is presented here.

Test Pit 1

Spit	Charcoal (g)	gastropods (g)	Bone (g)	Weight of stone artefacts (g)	Number of stone artefacts	Ochre (g)	other (g) - seeds
1							
2	0.2		0.5	1.2	1		0.2
3							
4							
5							
Total	0.2	0	0.5	1.2	1	0	0.2

Test Pit 2

Spit	Charcoal (g)	gastropods (g)	Bone (g)	Weight of stone artefacts (g)	Number of stone artefacts	Ochre (g)	other (g) - seeds
1							
2				16.4	10		1.1
3	0.2	0.1		2.1	5		
4	0.3	0.1		5.7	8		
5	0.1			8.1	5		
6	0.1			5.4	2		
7				3.3	3		
8				5.2	2		
Total	0.7	0.2	0	46.2	35	0	1.1

Test pit 3

Spit	Charcoal (g)	gastropods (g)	Bone (g)	Weight of stone artefacts (g)	Number of stone artefacts	Ochre (g)	other (g) - seeds
1							
2		0.3	0.2				
3			0.3	11.6	14	17.7	
4	0.2		0.3	21.6	5	47.8	
5				1.1	2		
6	0.2			2.3	2		
7	0.4		0.4	1.6	1		
Total	0.8	0.3	1.2	38.2	24	65.5	

Table 6.23: Finds recovered from all test pits at Gamanyi, Riversleigh, northwest Queensland.

Summary

Gamanyi is highly significant to the local Aboriginal people. Aboriginal people occupied the area around the Gamanyi caves and ventured inside sometime in the last 1,000 years. Use of the site appears to have been very limited. The fact however, that Gamanyi was visited during the late Holocene at all, given its distance to water and accessibility problems is a strong indication that Aboriginal people were exercising high levels of foraging mobility at this time and utilizing patches with far less certainty of encounter and with lower ranking resources. The reasons for this are discussed in chapter 8.

6.5 Chapter Summary

This chapter has presented the results of survey and excavation that focused on the Riversleigh area of the study region. In 2002 this research focused on areas close to the Gregory River. During 2003 fieldwork expanded out from the Gregory to sample the entire Riversleigh landscape.

The results of excavations at sites in the Riversleigh area provide evidence for early colonisation of the region with occupation spanning all the climatic phases of the settlement model. The expectations of the diet breadth and patch models have been well met by the evidence of changes in subsistence strategies at the different sites, in different patch types and during different climatic phases. No more evident is this than in the expansion and specialization in low ranked mussel shells at GRE8 during the LGM. Other sites including the OLH midden, which provides evidence supporting the larger scale regional patch model, where certain areas (such as OLH) provided enough clumped resources, to allow for large aggregations of people for extended periods of time. These areas have been found to directly correlate with the location of tufa dams along the course of the Gregory River; places that provided ideal habitats for people and fauna and in addition to proximity to good quality stone raw material.

It is interesting that it has only been in the very late Holocene that the more marginal areas of Riversleigh were occupied. This broadly correlates with the amelioration of conditions following the mid Holocene El Nino period of enhanced aridity, which people to use these more marginal sites for a variety of tasks, including short term camps and for ritual practices.

Chapter 7

Excavation in the Northern Study Area – Lawn Hill, Musselbrook and Elizabeth Creeks

7.1 Introduction

Chapter 7 presents the results of excavations in parts of the research region beyond Riversleigh. This fieldwork included Lawn Hill, Musselbrook and Elizabeth Creeks and their surrounding environments. These investigations broadened the focus to examine the timing and nature of the spread of people across the entire study region. Survey of Danjadanja near to Lawn Hill Creek was undertaken in addition to excavations at Bandangala 1, a sandstone rockshelter beside the permanent watercourse Musselbrook Creek, AL:B37, a large rock art complex site near to Elizabeth Creek, and Wild Dog Dreaming, a midden site along Lawn Hill Creek (Figure 7.1).

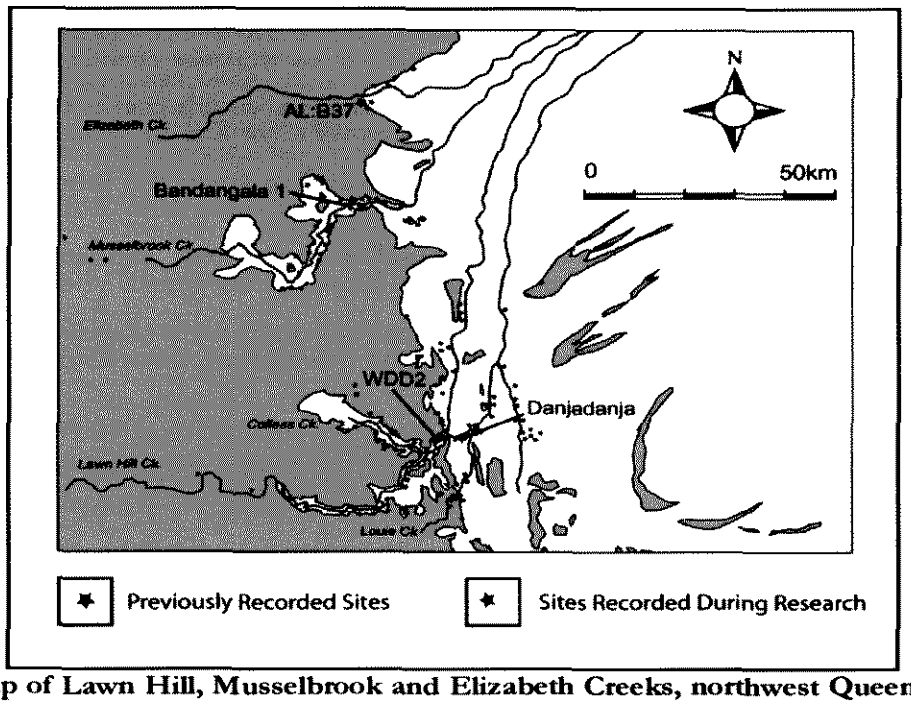

Figure 7.1: Map of Lawn Hill, Musselbrook and Elizabeth Creeks, northwest Queensland showing the location of previously recorded sites and sites recorded during this project. Sites that have been excavated are labeled by name.

7.2 Lawn Hill Creek

7.2.1 Wild Dog Dreaming

Wild Dog Dreaming is a small rockshelter with an associated shell midden adjacent to the south bank of Lawn Hill Creek (Figure 7.2). The site is an important to the Waanyi community and they maintain strong connections to Dreamtime stories expressed in both the 'natural' features of the mesa, and the rock-art that features on its surface. Wild Dog Dreaming is one of a suite of sites, including those excavated by Hiscock which occur within a 2 km radius of the central Bujabuja gorge system at Lawn Hill. Excavation at Wild Dog Dreaming aimed to provide a comparative dataset and an assessment of the occupation history of this locale. Furthermore, this excavation enabled the direct comparison of cultural material found in close association with the featured rock-art, which at this location includes styles which are perhaps very old, combined with more recent styles and motifs (Walsh 1983; Border 1988).

Site Setting

Wild Dog Dreaming is located approximately 2 km downstream and east from Colless Creek Cave on Lawn Hill Creek. It is less than 500 m from the commencement of the sandstone escarpment of the Constance Range formation, which marks the transition from black soil plains to plateau. Wild Dog Dreaming is 100 m from the junction of Lawn Hill Creek and a small tributary which skirts around a prominent sandstone mesa formed within the main Duwadari gorge at Bujabuja, called Wayinggulami (Figure 7.2).

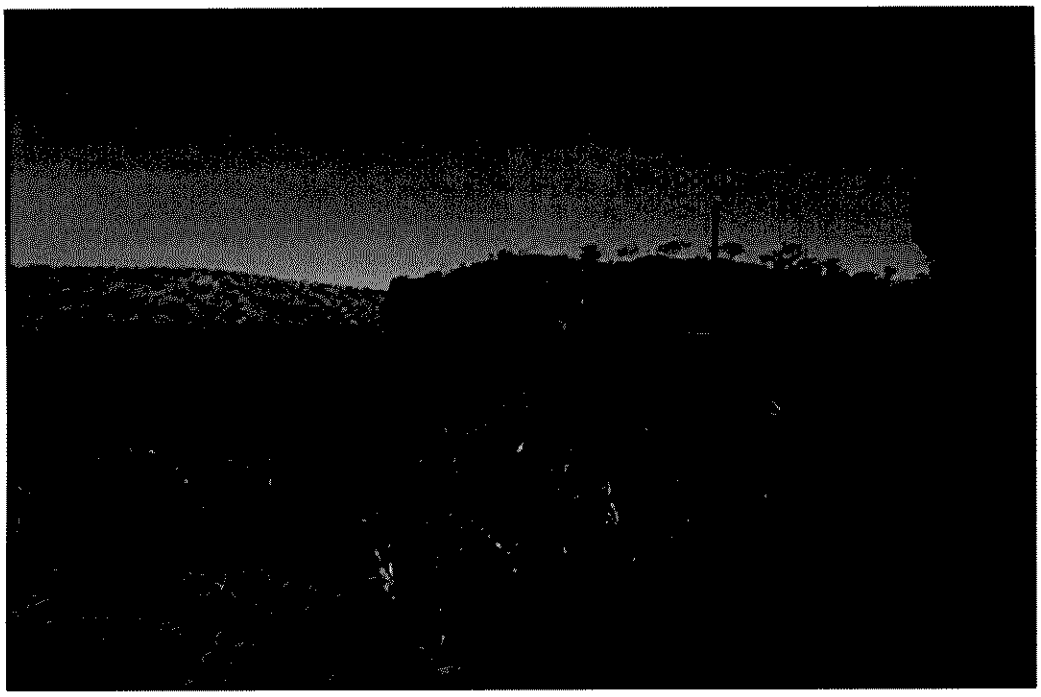

Figure 7.2: The Wayinggulami formation showing the location of the Wild Dog Dreaming site complex. Vegetated area in foreground contains abundant lithic scatters and deflated middens. A small tributary of Lawn Hill Creek is to the left of the photograph and Lawn Hill Creek is in the immediate foreground.

The small tributary to the east of Wayinggulami has created a large levy bank on the western side, much like the levee found at Louie Creek, and formed during rapid sedimentation in wet season flooding. The levee, which is approximately 400 m x 100 m, features extensive lithic scatters of R-chert and small deflated middens of mussel shell (most no larger than 2 m x 2 m). Wayinggulami is a large isolated mesa of the Constance sandstone formation and is about 300 m long, 200 m wide and 30 m high. Rock-art features prominently along the base of the Wayinggulami formation, and includes both freehand painted bichrome motifs and engravings.

The actual site chosen for excavation is placed within an extensive woodland patch which is adjacent to thick riparian vegetation and large free-standing bodies of water associated with Lawn Hill Creek and tributaries. Resource abundance is high and the patch is very fine grained. It is likely that during dry periods this location featured aggregations of fauna.

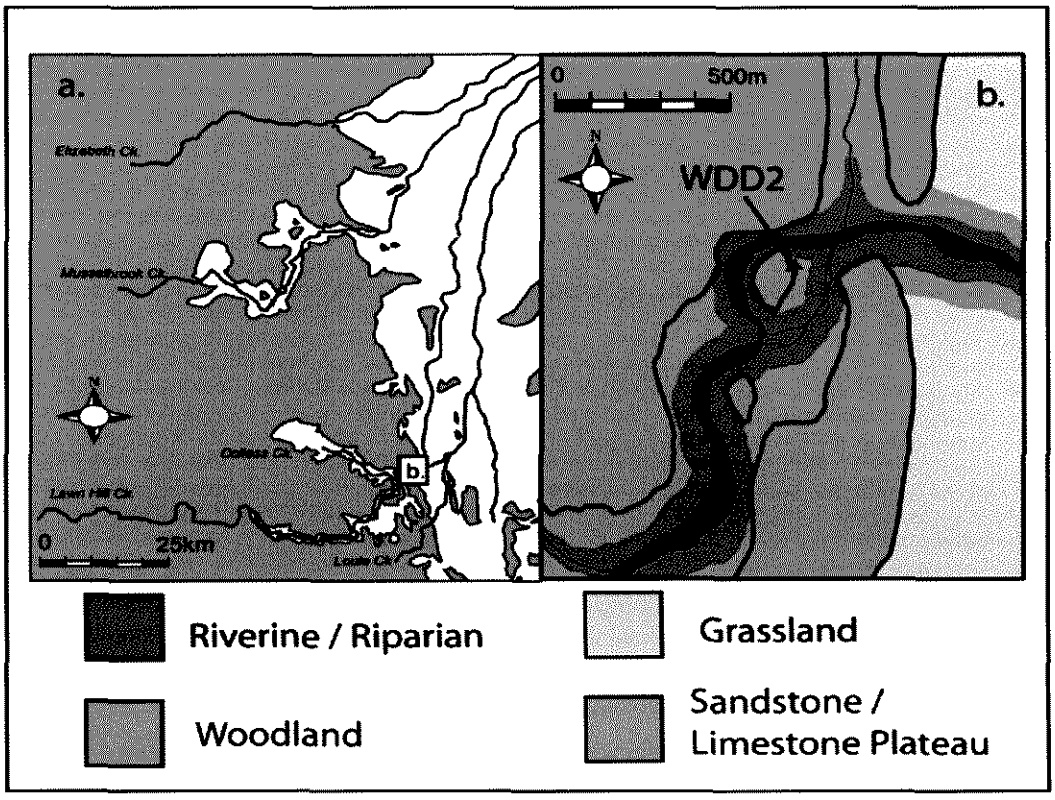

Figure 7.3: Location of WDD2, Lawn Hill northwest Queensland. Map a. shows the general location of the area marked as b. Map b. details the location of WDD2 and its relationship to local patch types.

At Wild Dog Dreaming, a large slab of fallen sandstone 20 m x 10 m is lodged against the vertical cliff forming a rockshelter and sediment trap (Figure 7.4). A surface scatter of mussel shell, lithics and post-contact material occurs within and outside the shelter. On the outside of the large boulder a second shelter (or overhang) occurs. An area below the overhang of 30 m x 20 m features an extensive and rich midden of mussel shells and surface scatter of stone artefacts. Original site recording forms indicate no distinction between the rockshelter and the overhang (EPA site AL:A33, Walsh sites BLA:8807, 8808, and 8809). In September 2004 a test excavation was completed at the overhang site (henceforth referred to as Wild Dog Dreaming 2 – WDD2).

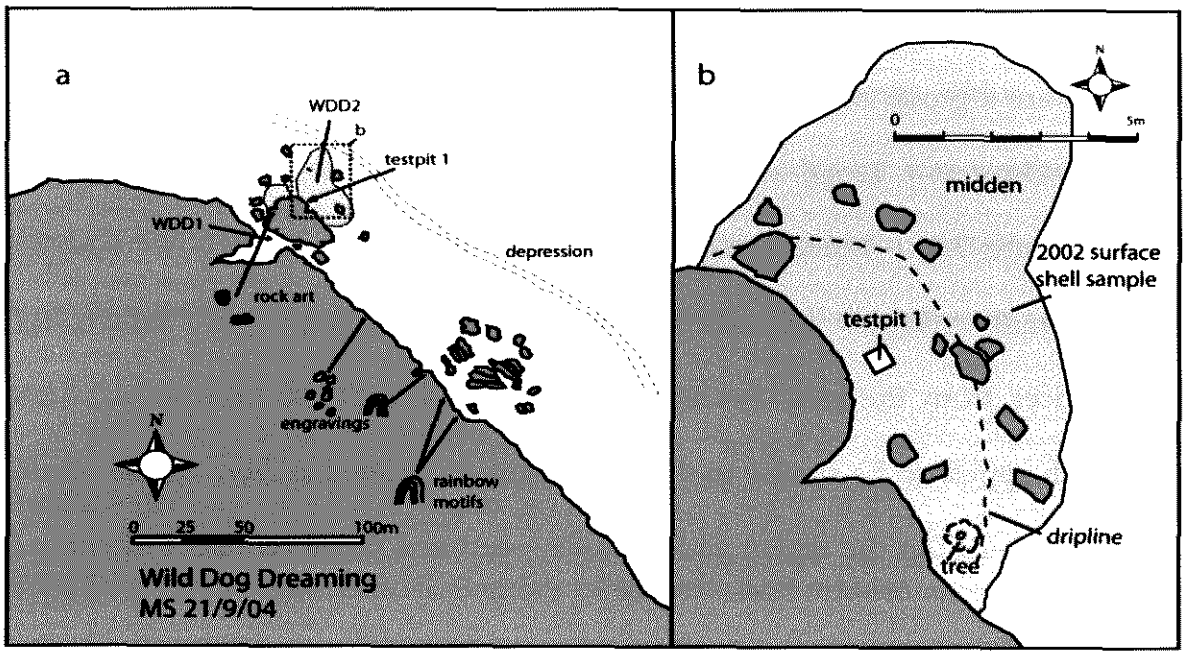

Figure 7.4: A. The location of the Wild Dog Dreaming site in relation to the Wayinggulami mesa formation. Inset B. is a site plan showing the location of the testpit excavated in 2004, the location of surface shell sampled for radiocarbon dating in 2002 and the extent of the midden deposit.

The Wayinggulami formation in the vicinity of Wild Dog Dreaming 2 features numerous panels of rock – art including engravings, freehand painting, and drawings. Bichrome rainbow motifs up to 1.5 m in height appear at regular intervals around the base of Wayinggulami, and adjacent to Wild Dog Dreaming two paintings occur within 25 m. The rock art has been accorded different interpretations by Aboriginal people over the last 20 years (see Walsh 1985; Border 1988; Dymock 1993). For the Waanyi, the creation of the rock formation and painted art is known, however the meaning of the engravings is less certain. The engravings have been argued to be of much greater antiquity compared to the rest of the rock-art, perhaps Late Pleistocene in age (Walsh 1985). The position and appearance of the engravings on the Wayinggulami face indicate that their production may not have been contemporary with the painted motifs. The engravings are all small circles that have been pecked into the sandstone with a central dot. Over 60 examples have been documented along Wayinggulami, and have been described by Waanyi and researchers as either eyes or springs.

The painted art at Wayinggulami occurs in two main areas. At the northern entrance of the rockshelter there are a group of motifs, including baskets and bird tracks, painted in red and white monochrome. Large rainbow-like motifs are found along the base of Wayinggulami (Figure 7.5). These images have been interpreted as rainbows and the Wangalla Boodjamulla (rainbow serpent). Images of Waanyi engaging in "Wild Dog" ceremonial practices from the early twentieth century show males dressed in elaborate headdresses which appear to be similar to the Wayinggulami painted arches. These motifs occur frequently throughout the region and are today seen as a visual reminder of cultural identity.

Figure 7.5: Jackson Diamond showing examples of painted arch designs, Lawn Hill northwest Queensland.

Excavation

A 50 cm x 50 cm testpit was excavated at WDD2 in the midden deposit where sediment was considered to be estimated by probe testing. This testpit was located 55 cm from the

side of the shelter, 4 m from the edge of the surface scatter of shell, and 1.75 m from the dripline of the shelter. Excavation proceeded in 5 cm spits within stratigraphic units. Finds were collected *in situ* where possible, and all sediment was weighed and dry sieved through 4 mm and 2 mm mesh, on site. Finds from the 4 mm fraction were sorted on site, and all material recovered from the 2 mm mesh plus a bulk sediment sample was retained for further analysis in the Sydney University laboratories.

Stratigraphy

Wild Dog Dreaming 2 deposit consists of a dense shell midden approximately 20 cm deep. Excavation ceased at a depth of approximately 35 cm, as no cultural material was evident and large weathered pieces of sandstone rubble were more frequently encountered. Four stratigraphic units were identified. The basal Unit A (35 - 25 cm) consisted of orange-red compacted sterile sediment. Unit B (25 - 12 cm) comprised grey sandy sediment. Towards the bottom of this unit the band of shell diminished (depth of approximately 20 cm). Unit C (12 – c. 8 cm) consisted of darker and compacted brown sandy sediment. Stratigraphic Unit D (0 – c. 8 cm) consisted of the upper loose brown sandy sediment (Figure 7.6).

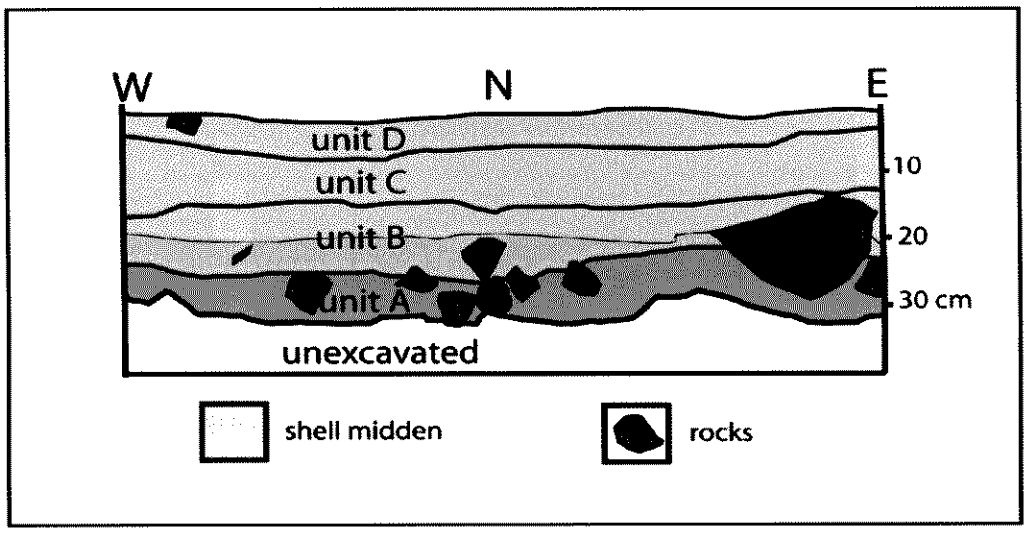

Figure 7.6: Section profile of testpit 1 at the Wild Dog Dreaming 2 site, Lawn Hill, northwest Queensland.

Chronology

Three radiocarbon determinations on freshwater mussel shell were obtained from samples collected *in situ* from spits 1, 3 and 6. An additional shell sampled from the edge of the midden at the lowest and most deflated part, had been dated previously (2003) and returned a radiocarbon determination of 2760 ± 45 (Table 7.1).

ANSTO Code	dating medium	δ(^{13}C) per mil	percent Modern Carbon		Conventional 14C age		Calibrated Age (Cal BP)
			pMC	1σ error	yrs BP	1σ error	
OZH618 (spit 1)	freshwater mussel	-10	73.18	0.43	2510	50	2533.5
OZH617 (spit3)	freshwater mussel	-9.8	71.22	0.69	2730	80	2743.5
OZH626 (spit 6)	freshwater mussel	-8.9	74	0.45	2420	50	2445

Table 7.1: Radiocarbon determinations for Testpit 1, Wild Dog Dreaming 2 site, Lawn Hill.

The radiocarbon determinations for Wild Dog Dreaming 2 indicate that the midden accumulated rapidly in the Late Holocene at around 2,600 years ago. As seen at the OLH site on the Gregory River, WDD2 formed in just a few hundred years. The Wild Dog Dreaming 2 site provides another snap shot of the activities of hunter-gatherers in this area of Lawn Hill Creek. The rapid deposition points to intensive use of this area for a short period, and the timing of the occupation coincides approximately with the climatic amelioration of the ENSO in northern Australia (Turney *et al.* 2002; Torgersen *et al.* 1988).

Flaked Stone Assemblage

A small assemblage of flaked stone artefacts was recovered from the testpit excavation (n=37). Thirty (30) non-diagnostic fragments which may be the result of human knapping were also recorded. All stone artefacts were recovered from the matrix of the shell midden to a maximum depth of 19 cm.

The Wild Dog Dreaming assemblage consists predominantly of chert, available from gravels at Lawn Hill Creek less than 100 m distant to the site. One silcrete and one greywacke flake were also identified. The silcrete probably derives from the lateritic duricrust of the Wayinggulami formation under which the Wild Dog Dreaming site occurs, whilst the greywacke has most likely been transported from a distance of at least 3 km from either Pages Creek, Dinner Creek or Edith Springs quarries. On the blacksoil plains it is the only non-local raw material present (see Hiscock 1988:134-6).

The flaked stone assemblage ay WDD2 is dominated by complete and broken unmodified flakes, plus two heavily reduced chert cores. One of the unmodified flakes is consistent with a tula pre-form as it is larger than most other flakes, has a gull-winged platform and a large bulb of percussion.

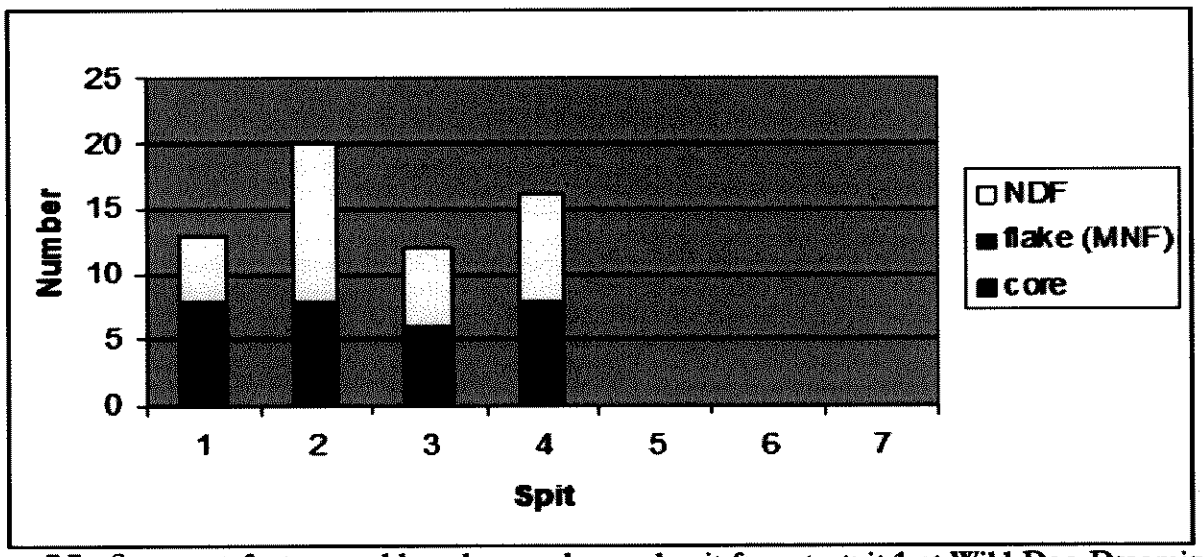

Figure 7.7: Stone artefact assemblage by number and spit from testpit 1 at Wild Dog Dreaming 2, Lawn Hill, northwest Queensland.

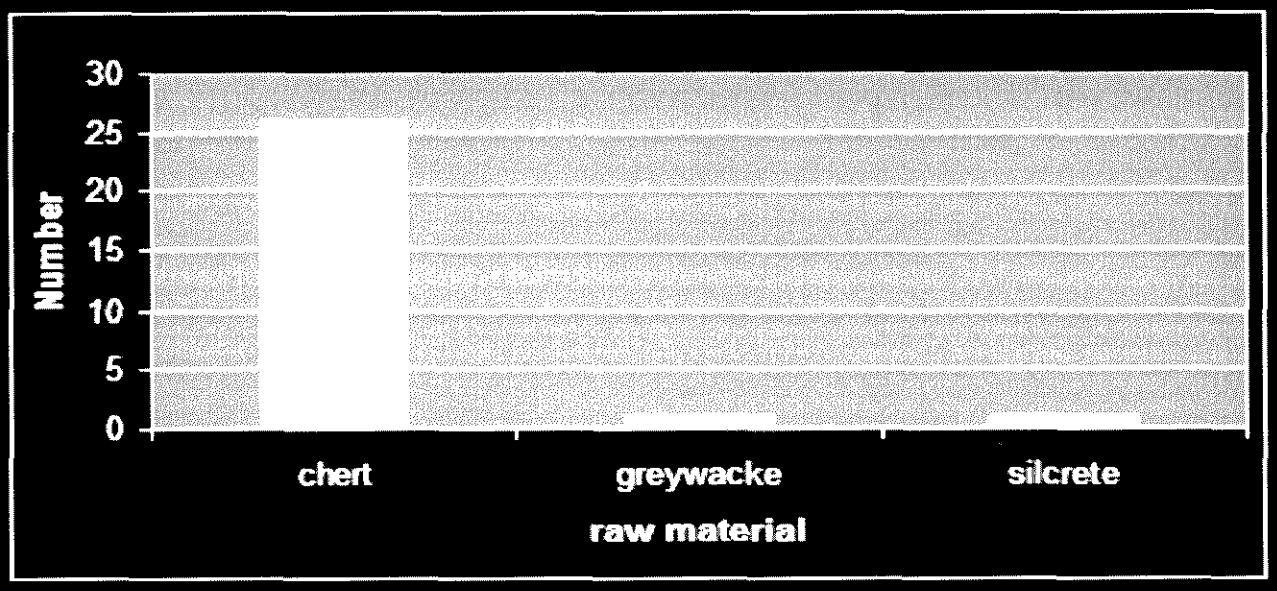

Figure 7.8: The total abundance of flaked stone artefacts by number and raw material type from Wild Dog Dreaming test pit 1, Lawn Hill, northwest Queensland.

Attributes measured for the WDD2 flaked stone assemblage were size, frequency of breakage, knapping skill and applied force, and measures of the extent of reduction. The average size of flakes is variable, though it can be noted that chert flakes are relatively round/square. The mean length of complete flakes was 24.39 mm and the mean width was 20.91 mm. There was little dorsal cortex on flakes, indicating that initial stages of reduction took place elsewhere (Table 7.2).

Spit and depth	Complete flakes	MNF	total weight	number of artefacts / m³
1 (<1cm)	5	8	32.3	3200
2 (4.875cm)	6	7	16.9	574
3 (4.125cm)	1	6	5.7	582
4 (5.5cm)	5	7	22.3	509
total	**17**	**38**	**77.2**	**4365**

Table 7.2: Frequency of flake discard from testpit 1 at Wild Dog Dreaming 2, Lawn Hill, northwest Queensland.

Cortex %	n	Average flake length (mm)	Average flake width (mm)	Average flake area (mm2)	Average flake weight (g)
0	12	15.72	16.645	261.6594	2.39 (s.d.=2.37)
1-24	1	39.57	28.64	1133.2848	12.9
25-49	-	-	-	-	-
50-74	-	-	-	-	-
75-99	1	20.45	15.73	321.6785	3.15
100	3	21.82	22.64	494.0048	3.93 (s.d.=5.28)

Table 7.3: Percent cortex on distal surfaces of complete flakes from Wild Dog Dreaming 2 testpit 1, Lawn Hill, northwest Queensland. The measurements for the single flake with 1-24% cortex are from the tula pre-form, hence the discrepancy in size with increased reduction.

Broken flakes comprise almost half of the assemblage, most of which exhibit transverse breakage. The majority of flake breakage probably occurred as the result of trampling, as the ratio of transverse to longitudinal breakage is 5 to 1 (Table 7.4). Distal flakes constitute 21% of the total assemblage whilst proximal and medial transverse breakages 13.1% in total.

flake breakage	frequency
flakes broken	42.1%
proximal fragments	10.5%
medial fragments	2.6%
distal fragments	21.1%
longitudinally cone split fragments	2.6%
fragments with both transverse and longitudinal breaks	5.3%
ratio of transverse to longitudinal breakage	5 : 1

Table 7.4: Frequency of broken flakes in testpit 1 at Wild Dog Dreaming 2, Lawn Hill, northwest Queensland.

Knapping Techniques

The Wild Dog Dreaming 2 assemblage is dominated by simple core reduction as demonstrated by platform type and size which shows that almost 50% (n=8) of all flakes from the deposit were produced on cortical platforms. Additionally, platforms exhibiting a single flake scar constitute 35% of the assemblage. With the exception of gull-wing platform types, the average platform area shows changes in size directly related to the stage of core reduction when the flake was removed. Flakes with cortical platforms are more than twice the mean size of non-cortical platform flakes.

Platform type	n	% with platform prep.	Average width (mm)	Average thickness (mm)	average platform area (mm^2)
cortical	8	0	10.68	4.92	52.55
single flake	6	0	7.14	3.42	24.42
multiple flake	1	100	8.44	2.72	22.96
gull-wing	2	50	24.34	7.87	191.43
shattered	1	n/a	n/a	n/a	n/a

Table 7.5: Flake platforms by type and dimension for artefacts from the Wild Dog Dreaming 2 testpit 1, Lawn Hill.

Terminations

Seventy six percent (n = 13) of all complete flakes feature feather terminations whilst the remaining 24% have hinge terminations (n = 4). Flakes with hinge terminations were smaller than the average size of flakes in the assemblage and were featured flaked platforms. Consequently flakes with hinge terminations are likely to have been produced late in the reduction sequence of the chert cores, when knapping problems were more

likely to arise. The alternative explanation that flakes with hinge terminations were the result of retouching flakes based on their size is unlikely, as there is no evidence of bipolar percussion.

Faunal Assemblage

Terrestrial faunal (n = 27 and total weight = 9.8 g) were associated with the midden deposition in spits 1 - 5. No fragments of bone were identifiable to species.

A dense midden feature consisting of freshwater mussel (*Alathyria pertexta spp.*) extends from the surface of testpit 1 through to a depth of approximately 20 cm. The shell accumulations occur through three of the stratigraphic units. Radiocarbon determinations on the shell all overlap at two standard deviations and it is most likely that the observed stratigraphic changes concern the preservational state of shells and increasing depth below surface. Units C (compact brown sediment) and D (light brown sediment) have the same texture and particle size, and colour differences are possibly due to the compaction of sediment and shell preservation. The grey Unit B sediment is most likely the result of the burning of shells onsite or greater deposition of burnt shell material, and is coincident with a peak in charcoal concentration (7.4 g).

All the shell was identified as the bivalve *Alathyria pertexta spp.* (W. Ponder, Australian Museum pers. comm.). NISP and MNI calculations are presented in Table 7.6. Shell increases by weight and number, peaking in Spit 4. Minimum numbers of individuals offer a better representation of the true abundance of material in the site and show that the peak of deposition occurs in Spits 3 and 4, tapering off in Spit 2. The ratio of MNI to NISP is relatively constant at 1:5 until the upper two spits where fragmentation increases considerably can be attributed to a period of *in situ* weathering and trampling.

Spit	mussel shell (g)	mussel shell NISP	mussel shell MNI	mussel shell MNI:NISP
1	220.2	437	14	1:31
2	637.1	1420	157	1:09
3	503	1162	203	1:05
4	720.7	1600	317	1:05
5	189.3	426	99	1:4.3
6	27.8	63	8	1:7.9
7	-	-	-	-

Table 7.6: Shell weight NISP, MNI and rate of fragmentation by spit from Wild Dog Dreaming testpit 2 deposit, Lawn Hill.

Summary

The Wild Dog Dreaming 2 assemblage is dominated by local chert and whilst the size, shape and lack of cortex on flakes are indicative of later stages of reduction, there is no retouch identified in the assemblage. Flake features including platform and termination types also suggest that there was no core rotation. These findings are not surprising given the proximity of the site to raw material sources. The production and maintenance of stone artefacts was not a focus of activity at WDD2, rather, the focus of activities surrounding the shelter was the consumption of shellfish. The excavated sample shows that the site was clearly frequently visited for a short period of time about 2,500 years ago.

This data is important as it provides evidence that human subsistence activities had effectively spread out from the previously occupied caves of the upper gorges of Lawn Hill and Colless Creeks by the mid to late Holocene. Sites like Wild Dog Dreaming 2 are probably the result of aggregations surrounding large free-standing pools of water with abundant resources. It is significant that this site post dates climatic amelioration, and indicates that the lower gorges (and probably the eastern plains) had become highly productive landscapes from c. 2,500 Cal BP. Large dense midden deposits like WDD2

might also indicate increases in local population size. The diet breadth model would predict that the consumption of shellfish during these good conditions would either be the result of increased pressure, most likely due to a combination of *(i)* increased population, and *(ii)* less clumping of higher ranked resources due to greater availability of water.

7.2.2 Danjadanji

Site Setting

Danjadanji is located on the south side of Lawn Hill Creek mid-way between Lawn Hill Gorge and a commercial camping ground called Adel's Grove. Covering an area of 0.5 km^2 the site consists of both fringing riverine, woodland and grassland patches. The intersection of these units occurs about 150 m from Lawn Hill Creek. Two main soil substrates occur, associated with the vegetation communities and consist of alluvial sediments of weathered limestone, tufa and gravel adjacent to the creek and in the creek banks; and hard, cracking clay associated with the black soil plain away from the creek and to the east of a low ridge. Resource abundance at Danjadanji is high within the woodland and riverine patches, but notably less than other areas where Lawn Hill Creek is more substantial. On the grasslands there are few fauna and patch grain is coarse. As such, this area is predicted to have varied in resource density correlated with changes in climate and water availability.

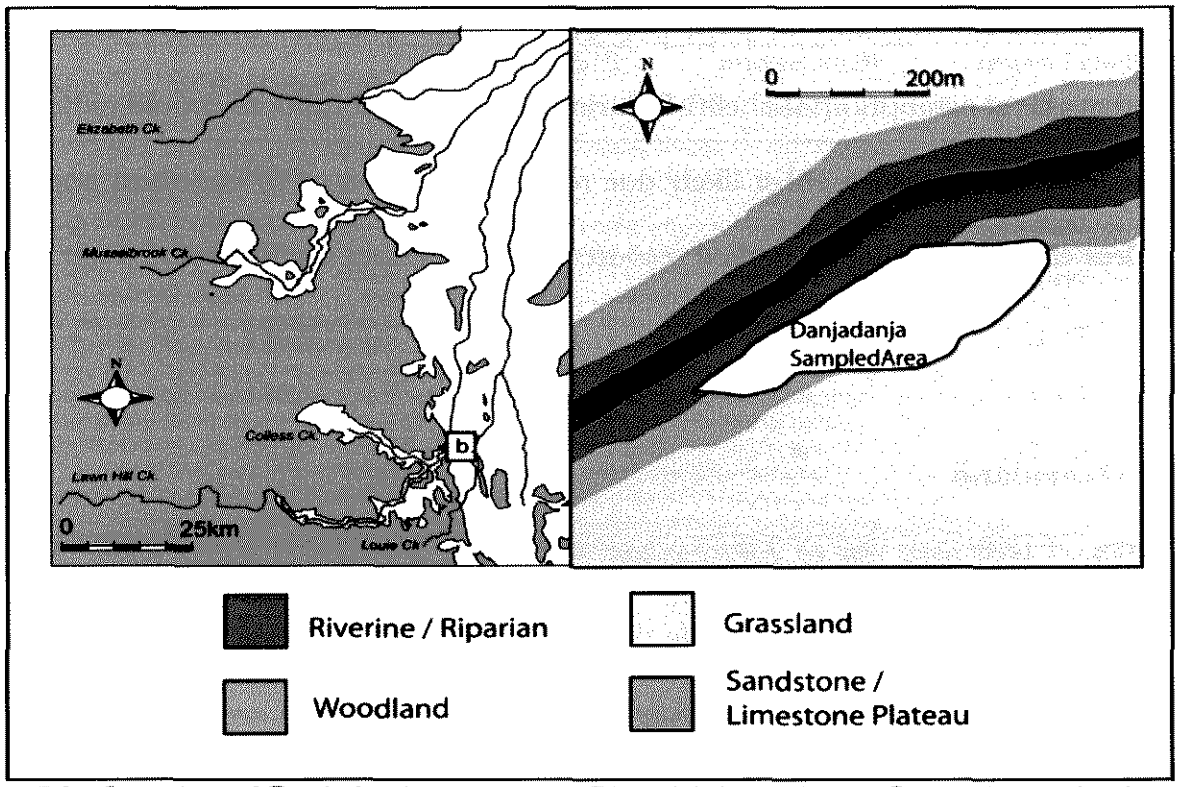

Figure 7.9: Location of Danjadanji survey area, Riversleigh northwest Queensland. A. shows the general location of the area marked as b. B. details the location of the Danjadanji sample and its relationship to local patch types.

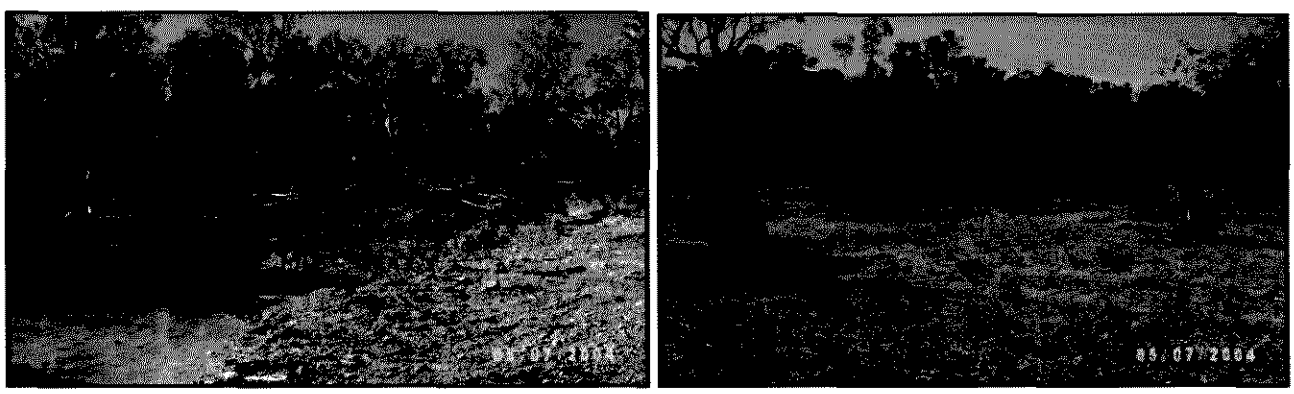

Figure 7.10: Lawn Hill Creek at Danjadanji, Lawn Hill, northwest Queensland (a) shows gravel banks which are the probable source of chert (b) shows a view of collection square 8 at transition to grass plains environmental zone.

At Danjadanji an increased concentration of stone artefacts occurs in an area approximately 200 m x 100 m. Stone artefacts varied in frequency across this area from less than one artefact per square metre to more than 6 artefacts per square metre. A range

of isolated artefacts (e.g. stone, metal, ceramic and glass) occur throughout and continue beyond the study area.

Sampling Methods

For the purposes of sampling and estimating artefact frequency, the study area was divided into two surface collection areas: Surface Collection Area 1 comprised 12 locations (called 'collection squares'), where artefacts were clearly visible. In each collection square (8 m^2) all artefacts were collected. Surface Collection Area 2 included all of the study area beyond the 12 collection squares of Area 1. Only isolated finds were collected in Surface Collection Area 2, although discrete scatters of low artefact abundance were also recorded. Artefacts were generally much less numerous (<1/m^2) away from surface Collection Area 1 (refer to Figure 7.11 for map of Danjadanji and location of the collection squares and isolated finds).

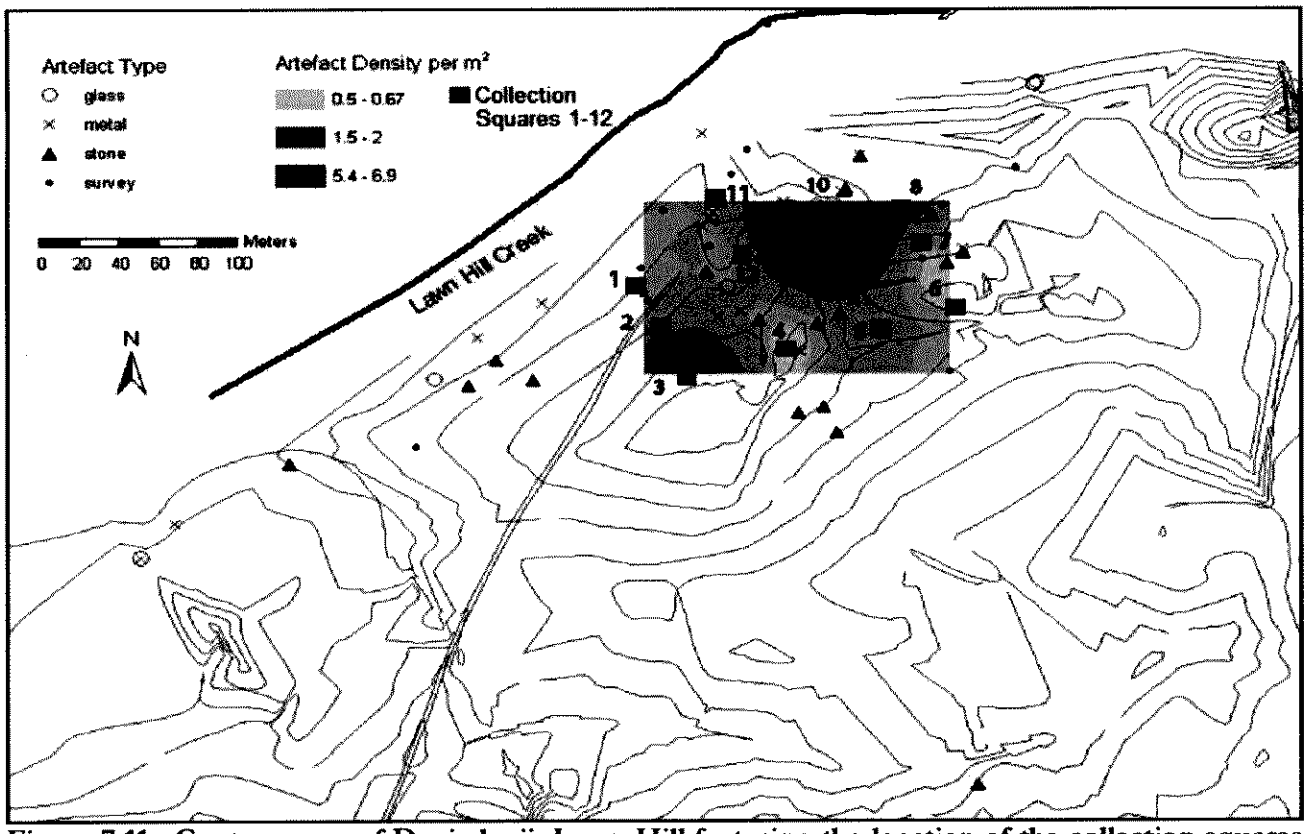

Figure 7.11: Contour map of Danjadanji, Lawn Hill featuring the location of the collection squares, isolated finds, and relative density of artefacts on the surface. Contour interval 0.2 m.

Surface Collection 1: Collection Square artefacts

Artefacts were collected from 12 locations in an area of about 50 m x 100 m. At each location a rectangle measuring 2 m x 4 m was set out, the area was photographed, and all flaked artefacts collected. At Collection Square 5 the square was extended to 2 m x 5 m because plants obscured the ground surface over about two square metres. All stone with fresh fracture surfaces and sharp edges was collected, even if they had no diagnostic indication that they had definitely been made by people. The reasons for this were that potentially usable chert cobbles occurred naturally in the area, and it seemed likely, on the basis of other sites, that many split cobbles were also artefactual, even though they lacked diagnostic evidence of deliberate flaking (Hiscock 1984a).

Within the sample area of c. 5,000 m^2, sampling covered 96 m^2, c. 2% of the total area. The sampling strategy encompassed those areas where artefacts were most abundant. Consequently, the estimates of artefact frequency per square metre for the sample area are likely to overestimate abundance.

Surface Collection 2: Isolated finds

The study area was surveyed on foot by 3 - 4 fieldworkers spread out several metres apart, recording small scatters and isolated artefacts whenever they were encountered. A small representative sample was collected. All larger items (visible from about 5 m - 10 m) were recorded. Effective coverage of the overall study area for the purposes of estimating isolated stone artefacts was probably in the order of 10%.

Excavation pits: Subsurface finds

Following surface survey, four areas were selected for subsurface testing. The aim of excavation was initially to characterize the soil substrate and assess the subsurface concentration of artefacts. Four pits, each 50 cm x 50 cm were excavated in surface

collection squares 4, 9, 11 and 12. Collection Squares 11, 12 and 4 formed a transect moving away from the creek and included the two landforms in the study area (gentle slopes towards the creek and the ridge). Collection square 9 was one of two collection areas with high artefact frequency: n=49 (the other collection area with high artefact frequency being Collection Square 10, n=61). The time during which the surface artefacts had accumulated or been exposed on the surface is not known, although sediment appeared to be eroding on the ridge tops; stable if not accumulating on slopes down from the ridge towards the Creek; and eroding closer to the Creek bank.

Each of the test pits were excavated by hand in 1 - 10 cm spits, until no further artefacts were found. Excavated sediment was dry sieved through 4 mm mesh. The lowest spits were wet sieved with 2 mm mesh to ensure total recovery.

Stone artefact analysis

Stone artefacts include grinding stones (e.g. made of sandstone) and flaked stone (mostly made of chert and silcrete). Artefacts were found in varying frequencies across the study area, and concentrations are defined by analyses below.

Surface Collection 1: Collection Square artefacts

All artefacts found in Surface Collection 1 from the 12 Collection Squares including subsurface finds are summarized in Table 7.7. A total of 249 artefacts were recorded comprising 246 stone artefacts, one ceramic fragment and two pieces of metal. The average frequency of stone artefacts for Collection Area 1 is about 2.6 artefacts per square metre, ranging from 0.625 artefacts per square metre in Collection Square 4, to 7.625 artefacts per square metre in Collection Square 10.

Square / spit	Ceramic	Core	All Flakes	Grindstone Fragment	Metal	Retouched Flake	Total
1		1	9			1	11
2			13			2	15
3		2	24			3	29
4		1	4			0	5
5		5	7			1	13
6		1	5			2	8
7		1	5			1	7
8		1	16			2	19
9		12	29			8	49
9(spit1)			9				9
10		9	45			7	61
11		4	4		1	1	10
11(spit1)			1				1
12	1	1	5	2	1	2	12
Total	**1**	**38**	**176**	**2**	**2**	**30**	**249**

Table 7.7: All artefacts from collection area 1 at Danjadanji, Lawn Hill, northwest Queensland. The whole numbers in the first column refer to Collection Squares of 8m². Square/spit 9.1 = 9 (spit 1) and 11.1 = 11 (spit 1).

There were more non-diagnostic fragments than diagnostic artefacts in most, but not all, collection squares. The total number of non-diagnostic fragments and diagnostic artefacts represents a frequency of about 5.9 per 1 m^2 for the 12 collection squares. Non-diagnostic fragments in Collection Area 1 were more common than diagnostic artefacts, with an average frequency over all Collection Squares of about 3.3 fragments per square metre (Table 7.8).

Square ID	Number of Non-Diagnostic Fragments (n)	Number of Cores, Flakes and Retouched Flakes (n)	Total (n)
1	20	11	31
2	10	15	25
2.1	5	0	5
3	27	29	56
4	11	5	16
5	21	13	34
6	16	8	24
7	5	7	12
8	27	19	46
9	77	49	126
9.1	4	9	13
10	18	61	79
11	61	10	71
11.1	4	1	5
12	11	8	19
12.1	4	0	4
Total	**321**	**245**	**566**

Table 7.8: Non-diagnostic fragments and diagnostic artefacts from collection area 1 at Danjadanji, Lawn Hill, northwest Queensland. The whole numbers in the first column refer to Collection Squares of 8m². The numbers 2.1, 9.1, 11.1 and 12.1 refer to upper excavation units of 50 cm x 50 cm x 1 cm deep, within Collection Squares 2, 9, 11 and 12 respectively.

Surface Collection 2: Isolated finds

The survey suggests that metal and glass artefacts are equally visible over the landscape as stone artefacts (Table 7.9).

type	Number of locations	Isolated Artefact Collection number (refer to Figure 7.11 for location)
stone artefact scatter	5	-
Isolated cores	1	-
grindstones	1	20,21
retouched flake	6	1,2,4,5,13,15,19
unifacial point	9	6,7,10,11,16, 18,23
Grand Total	**45**	

Table 7.9: Number of artefacts and artefact scatters in collection 2 at Danjadanji, Lawn Hill, northwest Queensland. Note: IA collection numbers were allocated to assistants in the field, and missing numbers (8, 22, 24) between 1 and 25 were not allocated.

Subsurface finds

Only the upper centimetre of any of these pits contained artefacts, although estimates suggest they have a higher frequency than surface finds (Table 7.10). For example in collection square 9, there are 6.125 artefacts per m^2 (n = 49) on the surface and 36 artefacts per m^2 (n = 9) in spit 1. Various factors affecting the higher recovery rate from sub-surface excavation are: *(i)* the artefacts were found within 1 cm of the surface and are likely to be mixed by recent disturbance (e.g. trampling); *(ii)* sieving of excavated soil is likely to have retained small artefacts not visible on the surface. Although the size range of artefacts from square 9, spit 1, overlaps with surface collections, the weight of artefacts from spit 1 is lower than those artefacts on the surface. No artefacts were found below 1 cm depth, and it is thought that the (mostly) smaller artefacts within 1 cm of the ground surface do not represent significant *in situ* subsurface deposits, but, rather, downward movement of small fragments.

Square/ spit	Depth below surface (cm)	Sterile Substrate	Flakes (n)	Retouched flakes (n)	Cores (n)	Stone artefacts (n)	Non-diagnostic fragments (n)	Stone artefacts per m² (n)	Artefacts + non-diagnostic fragments per m² (n)
4	-	-	4		1	5	11	0.625	2
4.1	1		0		0	0	5	0	20
4.2	10		0		0	0	0	0	0
4.3	20	Hard clay	0		0	0	0	0	0
9	-	-	29	8	12	49	77	6.125	15.75
9.1	1		9		0	9	4	36	52
9.2	2		0		0	0	0	0	0
9.3	3	Gravel	0		0	0	0	0	0
11	-	-	4	1	4	5	61	0.625	8.75
11.1	1		1		0	1	4	4	20
11.2	5	Alluvium	0		0	0	0	0	0
12	-	-	5	2	1	8	11	1	2.375
12.1	1		0		0	0	4	0	20
12.2	10		0		0	0	0	0	0
12.3	12	Alluvium	0		0	0	0	0	0

Table 7.10: Stone artefacts and non-diagnostic fragments from excavations, including surface collection at Danjadanji, Lawn Hill.

Analysis of flaked stone

For collection Squares 1 – 12, a summary description of the artefacts was compiled which included the nature of flaking technology, and the extent of the site in its most concentrated area. Three research questions were addressed: *(i)* did the assemblage represent either contemporaneous, functionally discrete activity areas associated with a

single phase of occupation, or overlapping activity areas and multiple phase occupation over a long time period, *(ii)* what was the nature of site function, specifically how many activities were undertaken, *(iii)* and were chert cobbles, present in gravel beds in the area, exploited as a source for making stone tools?.

Artefact attributes

Basic description and preliminary observations indicated whether all or only some stages in the reduction process took place in the study area. The nature of the raw material, the range of techniques employed, control over flaking, and the frequency of particular technological classes were recorded to compare and contrast with the other Aboriginal sites recorded in the area.

Square ID	Number of Flakes + Cores + Retouched Flakes (n)	Minimum Number of Flakes + Cores + Retouched Flakes (n)
1	11	9
2	15	11
3	29	28
4	5	4
5	13	12
6	8	7
7	7	7
8	19	18
9	49	43
10	61	53
11	10	9
12	8	10
Total	**245**	**211**

Table 7.11: Number of stone artefacts and estimates of knapping episodes (excluding broken pieces) for each collection square at Danjadanji, Lawn Hill, northwest Queensland. Numbers in the second column (minimum number of flakes +cores + retouched flakes) are used in calculations for contour maps of artefact concentration

Artefact technological types

The Danjadanji assemblage is dominated by flakes and non-diagnostic fragments. Non-diagnostic fragments do not consistently track variation in flakes. Collection square 11 for example, has an unusually high proportion of non-diagnostic fragments relative to flakes. Collection squares 9 and 10 have good sample sizes for artefacts (flakes, cores and retouched flakes > 35). In these squares the proportion of cores to flakes is higher than in other squares. This may be the result of three possible mechanisms: *(i)* flake transport soon after manufacture; *(ii)* spatial variation in the reduction sequence for flaking relatively small, water worn cobbles; or *(iii)* variation in composition may simply reflect variation in sample size, the smaller samples being unrepresentative.

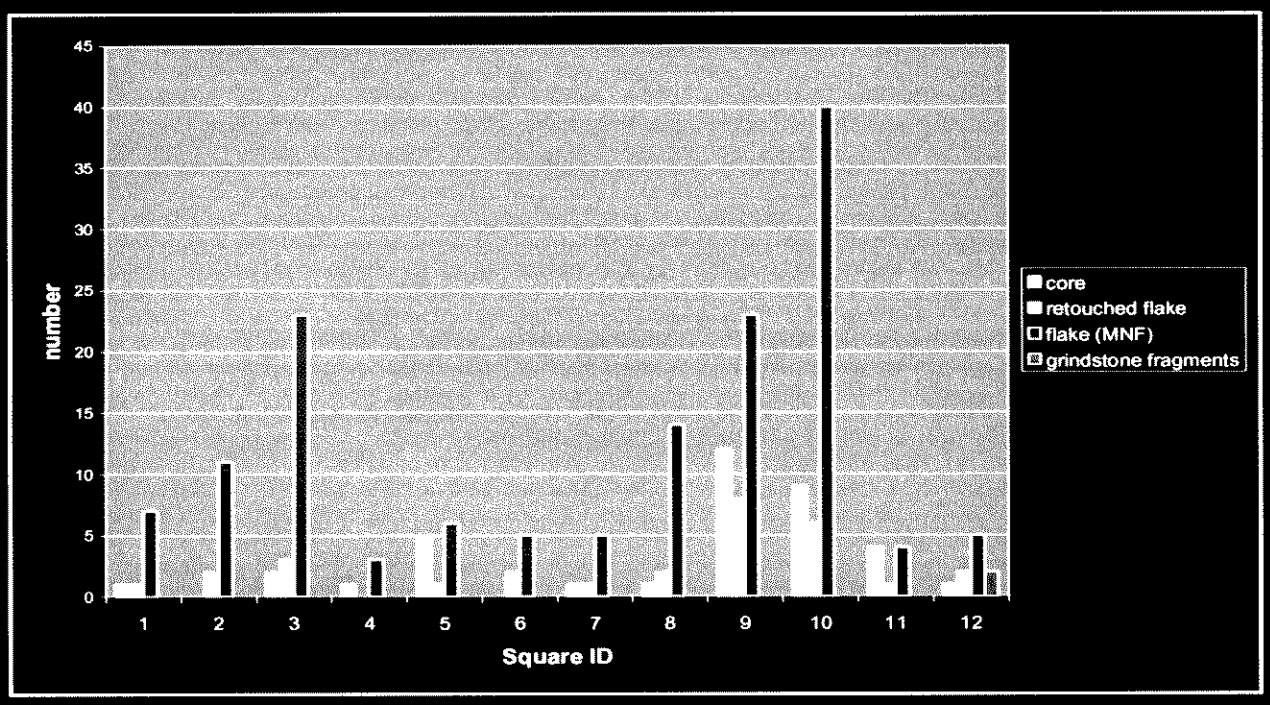

Figure 7.12: Artefact techno - types in Collections Squares 1-12, n=211 at Danjadanji, Lawn Hill, northwest Queensland.

Flakes vary in size across the study area with largest flakes found further away from the creek (Figure 7.13). Collection squares 1 and 11 had the lowest average flake length and

are the closest to the creek, while collection square 6 which had the highest average length is furthest away from the creek.

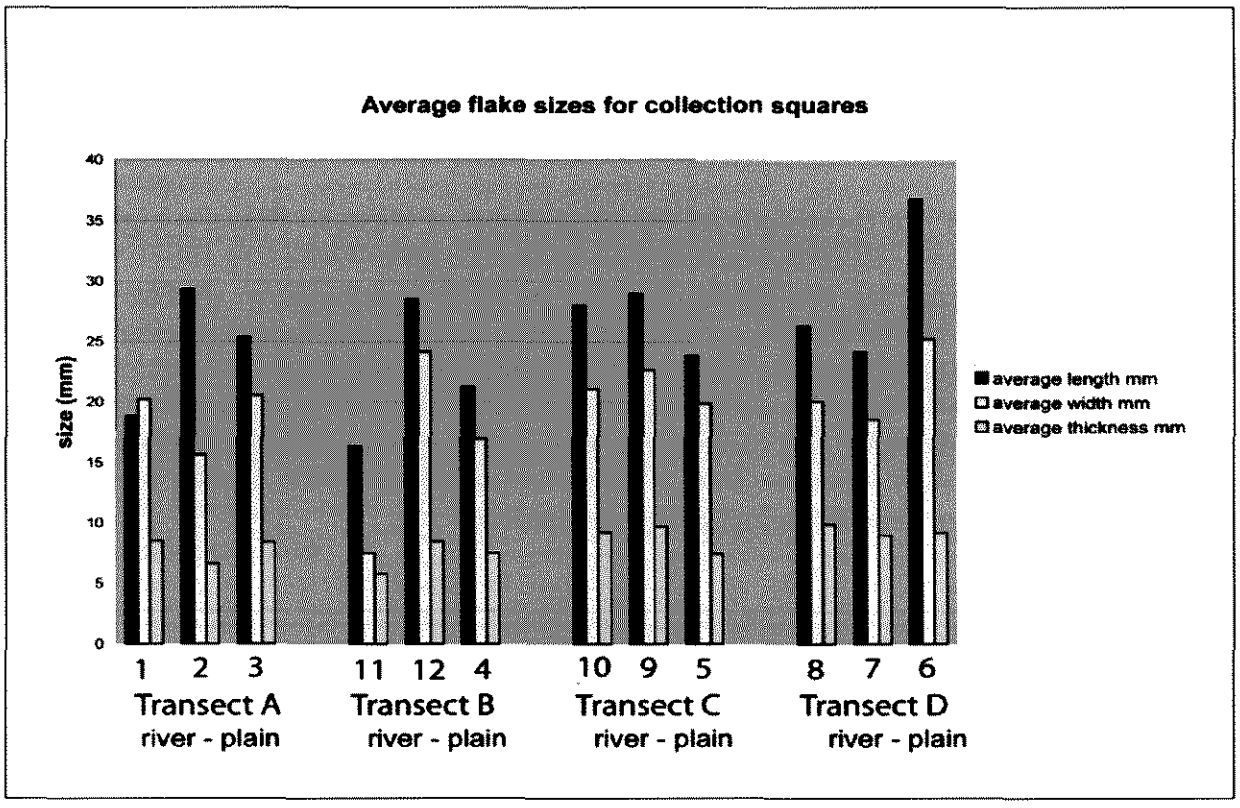

Figure 7.13: Average size of flakes (length, width and thickness) for all collection squares by transect perpendicular from Lawn Hill Creek, showing average sizes increasing in middle of transect before reducing with distance (n = 174), Danjadanji, Lawn Hill northwest Queensland. Note that the disparity in collection square 7 and 6 is probably due to a small sample size (n=7 for each of these squares).

In addition to the flaked stone, two grindstone fragments were recorded in Collection Square 12, and two grinding stones were recorded as isolated artefacts further to the northeast. A variety of projectile tips were found, including unifacial stone points (n=2 in Collection Squares, and n=9 from isolated finds), a shovel-nose metal spear point (n=1), and the tip of a crossbow arrow (n=1). A single chert tula slug was found in Collection Square 11.

Artefact reduction

The degree of artefact reduction has been assessed by the amount of cortex present on flakes, the presence of retouched flakes and the range of cores and flakes.

The variation in the amount of cortex noted is presented in Table 7.12. The amount of cortex on its own may be a poor indicator of reduction, because cortex may persist as part of an implement until late in its use life. For example, one of the three greywacke flakes recorded had 100% cortex on the dorsal surface, although the closest source of greywacke outcrops was more than 5 km away, much further than the chert sources. Nevertheless, > 50% cortex was frequently found in all collection squares. Given the small size of cores, and the natural occurrence of small usable cobbles in the study area, the abundance of cortex is likely to be a consequence of the local availability of small corticated chert nodules.

	cortex						
collection square	**0%**	**1-25%**	**26-50%**	**51-75%**	**76-99%**	**100%**	**n**
1	3	3		1		1	8
2	5	2	0	4	1	1	13
3	10	9	2	3		2	26
4		1			2		3
5	3	1		2		1	7
6	2	1	2		1	1	7
7		3	1	1	1		6
8	2	6	3	1	1	2	15
9	7	7	6	4	4	3	31
10	20	13	2	3	4	4	46
11	1		1	1		2	5
12	4	3					7
total	**57**	**49**	**17**	**20**	**14**	**17**	**174**

Table 7.12: Cortex on retouched flakes and flakes (MNF) from collection squares at Danjadanji, Lawn Hill, northwest Queensland.

platform type	n	average platform thickness (mm)	average platform width (mm)	average platform area (mm^2)
cortical	43	5.82	13.51	78.63
flaked	99	5.75	12.71	73.08
gull-winged	3	4.2	17.15	72.03
shattered	5	n/a	n/a	n/a

Table 7.13: Comparison of different platform types and average thickness, width and area from collection squares at Danjadanji, Lawn Hill, northwest Queensland.

Overhang removal is common among retouched flakes (approximately 50%) but is generally rare on other flakes (approximately 7%), suggesting that overhang was an important consideration in producing desirable flakes for further shaping, sharpening or other reduction. *Outré passé* flakes, sometimes considered as an error, or lack of control over flaking, comprise less than 6% of flakes and retouched flakes.

Although cores are sometimes heavier than flakes (as might be expected since flakes are produced from cores) there is considerable overlap in weight and size. A reason for this may be that cores can be split cobbles that leave no clear sign of being a flake (e.g. with a bulb or platform) or a core (with negative flake scars). Only after a split cobble has been retouched can it be identified clearly as an artefact, in which case it is classified as a core. Hertzian initiations may be lacking because cobbles can be split by placement on an anvil, a process that causes wedging propagation with no clear bulb of percussion. Impact points can be difficult to detect without microscopy, and may be absent due to breakage. Non-diagnostic fragments include many such split cobbles which might be expected where flaking (to test whether raw material quality) occurs close to the stone source.

Artefact concentrations

The distribution of artefacts for collection squares 1 - 12 suggests that the frequency of artefacts drops as you move further away from the creek. Although artefact frequency fluctuates in transects parallel to the creek, the distribution of isolated finds indicates that artefacts remain common close to the creek and decrease with distance from Lawn Hill Creek. This pattern is supported by other unpublished data (Slack 2002), that argued that concentrations of artefactual material occurred along this part of Lawn Hill Creek and at other locations in the region in the same way. Artefact concentration drops rapidly to the southeast to much less than 1 artefact per 100 m^2.

Artefact Discard

The survey has shown that activities were concentrated closer to the creek, where sediments appear to be either stable or aggrading, compared with erosion along the ridge. All but a few stone artefacts had sharp edges, suggesting that weathering from surface exposure was low, and that artefacts have not been exposed to weathering or damage from flooding or wind erosion. The presence of stone points, tula slugs and fragments of large grinding stones suggests Mid to Late Holocene occupation (within the last 5,000 years) in a marginal environment with scattered resources. A range of historic artefacts also documents recent occupation by Aboriginal people and others. The time frame of occupation cannot be further refined at this stage.

The low incidence of flaked stone prevents a clear indication of discrete activity areas. Artefact technological and functional classes suggest a range of activities which are dominated by manufacture and repair of stone artefacts. Evidence relating to food preparation and other activities is present but is less common than at other places along the creek. Rather than a single discrete phase of occupation, the stone assemblages suggest

overlapping activity areas with multiple phases of occupation by small groups of people over a long time period.

Site function

Several artefact types are present (grindstones, points, tulas) at the site but are only indicative of particular activities taking place. The tula slug has been reduced to threshold, and was in need of replacement when discarded. It was discarded, and perhaps replaced by a new flake at this location. The absence of hearths, bones and shellfish remains may be a consequence of adverse preservation conditions, but it is not considered likely as they are preserved at other locations along the creek. The absence of substantial amounts of shell suggests that the visits here were not for long periods of time. The frequencies of flakes, retouched flakes, cores and non-diagnostic fragments are consistent with short stop - over's involving repair and manufacture of stone tools.

Summary

Over 100 sites are known on the 'plain' near to Danjadanji (Border 1988; Hiscock 1988; Slack 2002) and include stone quarries and artefact scatters, some which are reported as knapping floors. As Hiscock found, distance to permanent water and suitable raw materials are the primary determining factors in site location and the intensity of landscape use in this region. There is some evidence for shell middens along Lawn Hill Creek out on the plains; however it is meager when compared to similar sites within the gorges. The paucity of material in the open sites on the plain is most likely due to a variety of taphonomic factors including large scale erosion over the last 100 years.

The nature of settlement and subsistence on the plains at Lawn Hill has been argued to date only from about 14,000 BP (see Hiscock 1988:248) and predominantly from the mid Holocene. This assertion is made in the absence of radiocarbon dating on any stratified

sequences built upon general observations concerning the nature of flaked stone materials and their state of weathering.

The Danjadanji site provides strong support for the models of stone artefact procurement and manufacture developed by Hiscock (1988) and provides evidence that Aboriginal people exploited the plains in foraging activities in the recent past, and procurement of raw materials from areas along Lawn Hill Creek at least during the last 2,000 years and possibly longer, dependent on uncertain patch richness.

7.3 Musselbrook Creek

7.3.1 Bandangala 1

Site Setting

Bandangala 1 rockshelter is located on Bowthorn pastoral station, adjacent to Lawn Hill National Park. The site is approximately 5 km west of the transition from the Gulf of Carpentaria savanna plain, within a sandstone gorge system on the eastern margin of the Barkly Tableland on Musselbrook Creek (Figure 7.14). Musselbrook Creek commences on the Barkly Tableland about 75 km west of the Bandangala 1 site and flows into the Gregory River approximately 100 km to the east. During the dry season (March - November), it is reduced to a series of large waterholes. Bandangala 1 is adjacent to one of these waterholes, which is 3 km in length.

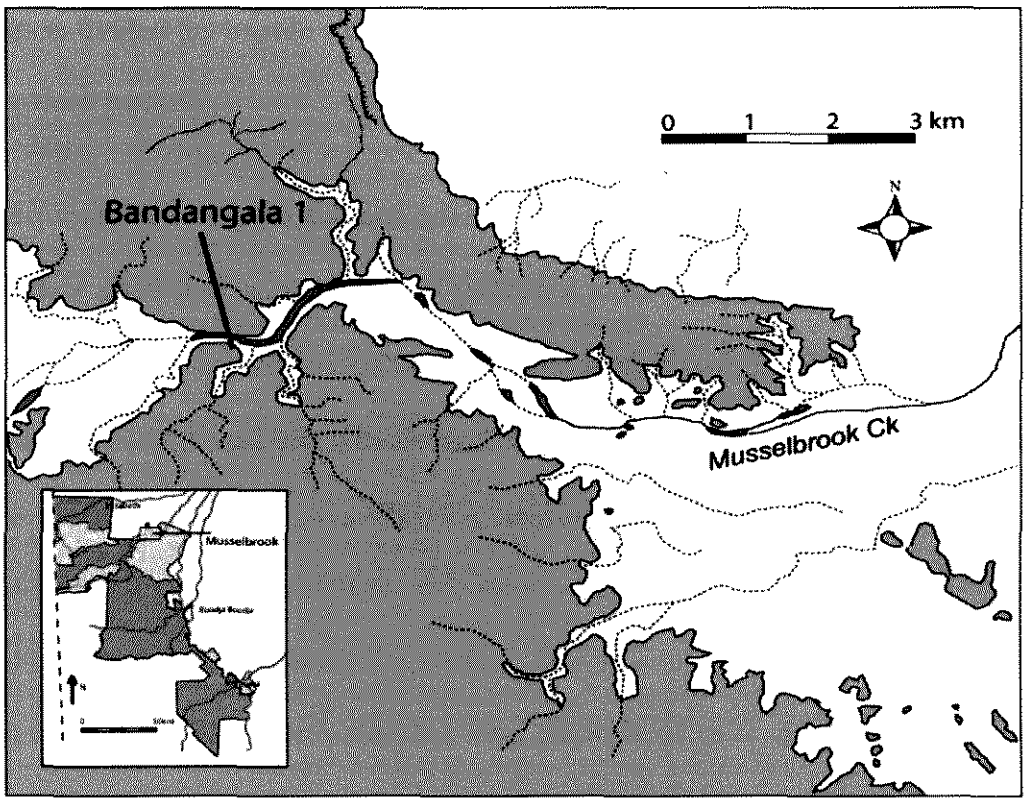

Figure 7.14: Bandangala 1, on Musselbrook Creek, northwest Queensland. Dotted lines indicate ephemeral streams. The sandstone escarpment is shaded orange, Late Pleistocene alluvial soils are unshaded.

Site Description

Bandangala 1 is located within a woodland patch adjacent to a very narrow riverine patch. This location is one of the most productive patch areas of the region, but it is far less resource rich than other areas already discussed such as the southern Gregory River. This is due to the seasonal and unstable nature of water flow in the north. Access to the site is restricted to the east and west as the site is not accessible from the sandstone plateau immediately to the south. Areas located within only a few kilometers along Musselbrook Creek open out to much more extensive woodlands patches. Due to the terrain of the escarpment to the south of Bandangala 1 it is considered unlikely that this patch was utilized in the past.

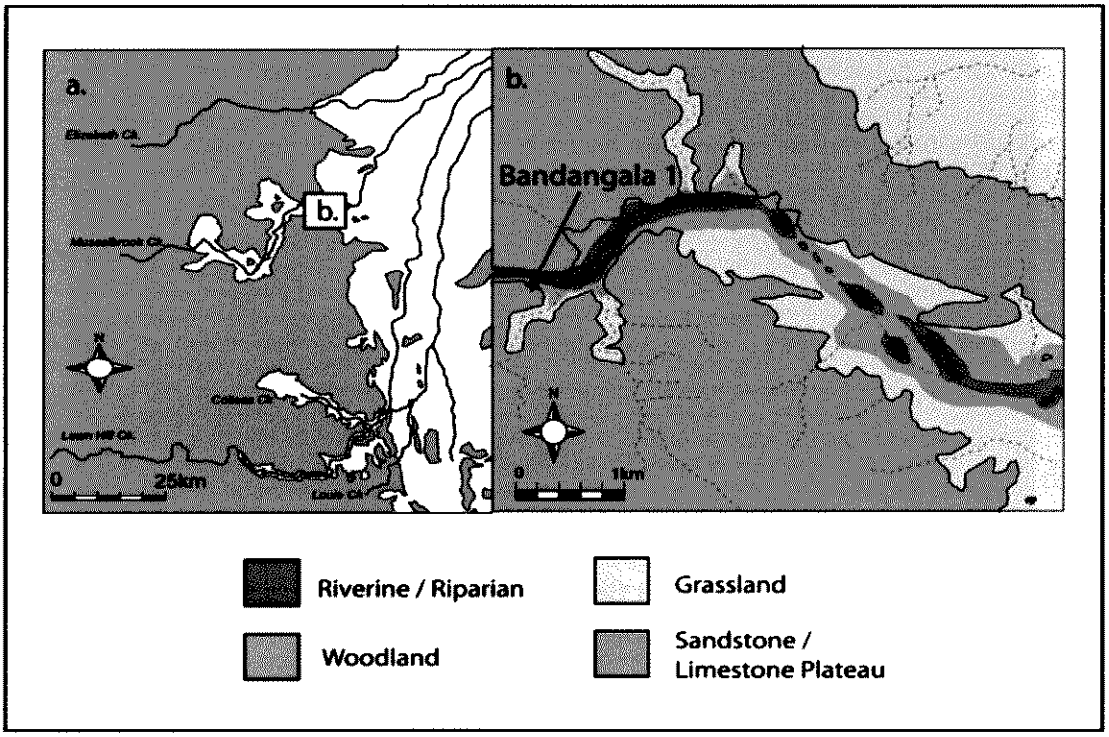

Figure 7.15: Location of Bandangala 1, Musselbrook, northwest Queensland. Map a. shows the general location of the area marked as b. Map b. details the location of the Bandangala 1 and its relationship to local patch types.

Bandangala 1 is a small sandstone rockshelter at the base of a sandstone escarpment containing an extensive shell midden. A surface scatter of mussel shell, flaked stone artefacts (including tulas, scrapers, and points), a large sandstone grindstone and a muller were identified in a 50 m^2 area under the escarpment overhang. Rock art consists of a partial bichrome red and yellow rainbow-like motif, well known from other sites in the region (see Border 1988, 1989; Slack 2002; Walsh 1985) and of a series of yellow painted emu tracks, and three hand prints.

Figure 7.16: Bandangala 1, on Musselbrook Creek, northwest Queensland, looking south.

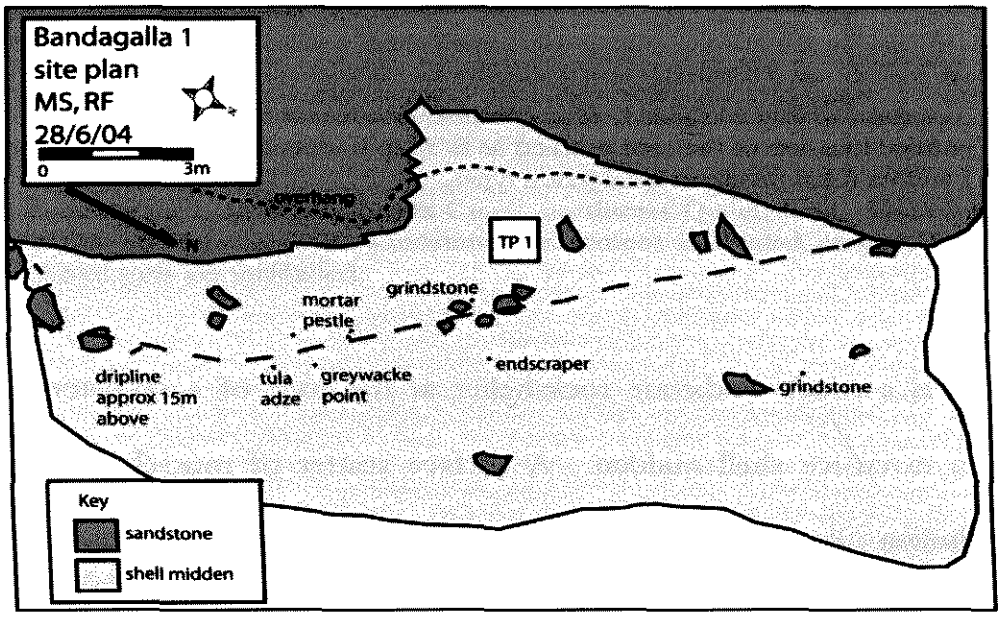

Figure 7.17: Bandangala 1 rockshelter, Musselbrook Creek, northwest Queensland showing location of testpit, extent of surface midden and surface lithic finds.

Excavation and stratigraphy

In July 2004 a 1 m x 1 m testpit was excavated within the Bandangala 1 shelter. Excavation proceeded in 5 cm spits within stratigraphic units to a depth of 99 cm (spit 19). Below this depth excavation continued in a 50 cm x 50 cm area in the northern corner of the square to a basal depth of 135 cm where a large slab of steeply sloping sandstone (possibly roof

fall) was encountered. All sediments were dry sieved through 4 mm and 2 mm mesh with some preliminary sorting completed on site. Two stratigraphic units were noted, including an ashy shell horizon approximately 15 cm below the surface. The lower unit, A, consisted of a compact red/brown sediment which occurred predominantly in the southwest side of the trench. Unit A sediments commenced from 22 cm depth and consisted of soil mixed with numerous flaked stone artefacts, faunal material and some shell. From 70 cm depth Unit A sediments account for over 50% of the volume of the deposit. At the base of excavations these Unit A sediments had expanded to cover approximately 90% of the trench.

Unit B consisted of a loose brown/grey sediment from the surface to about 140 cm depth. It was contained mainly to the northeast corner, and was comprised of a high density of mussel shell and ash. In some instances defined lenses of shell were observed. Unit B sediments featured very few flaked stone artefacts. During excavation it was further noted that the Unit B sediments overlay the Unit A sediment for the deposit.

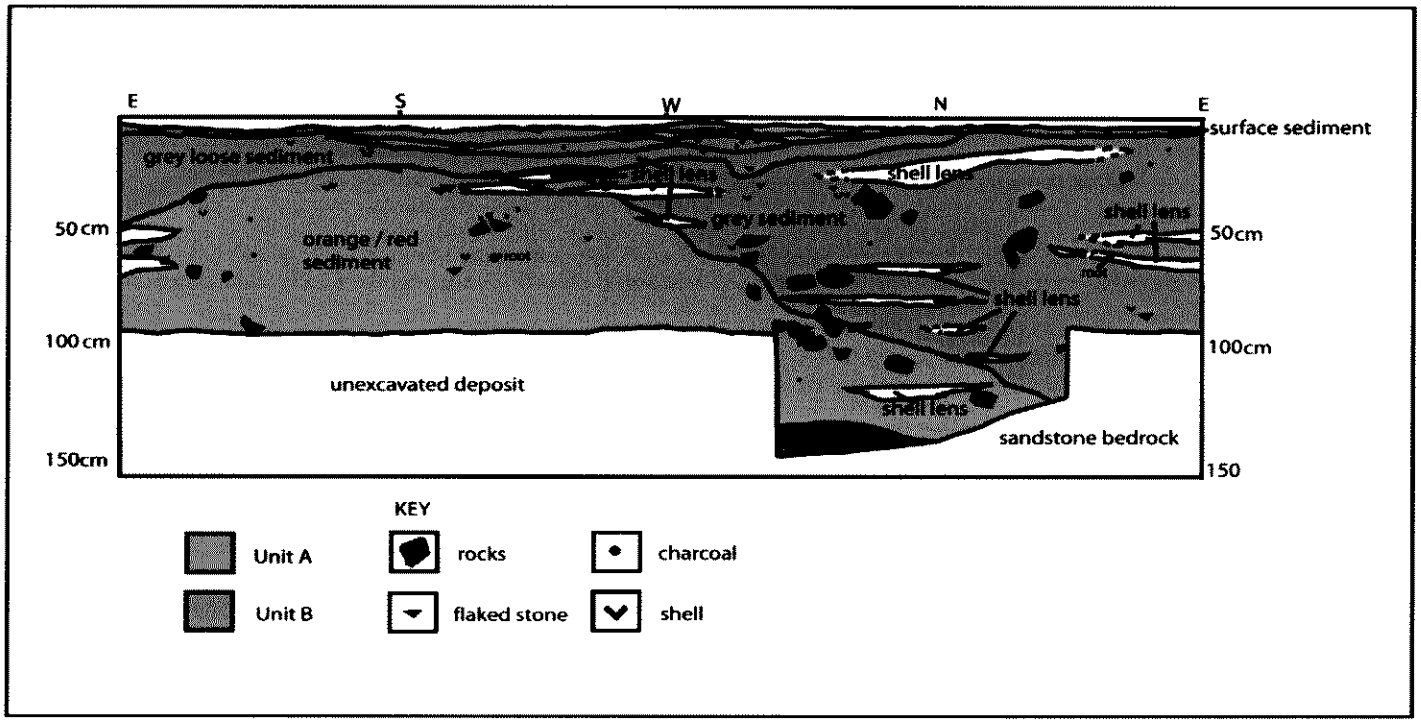

Figure 7.18: Section profile of Bandangala 1 testpit 1, Musselbrook Creek, northwest Queensland.

Chronology

Six radiocarbon determinations were obtained on charcoal and freshwater mussel shell (including a paired sample), recovered *in situ* and from column samples, from spits 2, 4, 12, and 23 of the testpit (Table 7.14). All charcoal samples were pre-treated with an acid/alkali/acid wash and the shell material was surface etched in the same way as GRE8 samples to remove the presence of any post depositional calcite. The radiocarbon determinations on paired shell and charcoal samples from Unit A (OZH 613 and OZH 612 respectively) were found to overlap at two standard deviations.

Spit	Depth (cm)	Sample material	Laboratory Number	dC13	Radiocarbon Age (yr BP)	Calibrated Age (yr cal BP 2st.dv)
2 (B)	7	charcoal	Beta-194878	-24.2 o/oo	200±50	150
4 (A)	16.35	shell	OZH613	-10.6 o/oo	2820±50	2874.5
4 (A)	16.35	charcoal	OZH612	-27.0 o/oo	2970±60	3064
11 (B)	53.2	charcoal	Beta-194876	-26.2 o/oo	680±40	607
12 (A)	58.2	shell	OZH614	-10.0 (est)	6120±60	6954
23 (B)	124.2	charcoal	Beta-194877	-26.1 o/oo	1360±40	1221.5

Table 7.14: Radiocarbon determinations Bandangala 1 shelter, Musselbrook Creek near Lawn Hill, Queensland.

An age-depth curve derived from Bandangala 1 shows that each stratigraphic unit accumulated at very different rates (Figure 7.19). The Unit B sediments appear to have accumulated at a very fast rate over the last 1,300 years in the northeastern side of the excavation. Sediment accumulation rates are between 100 - 200 kg/m^2/100 years for the most of the Unit B sequence. The radiocarbon determinations from the Unit A sediments show a much slower sedimentation rate beginning much earlier than the Unit B sediments. Sediment accumulation in Unit A is 10 - 15 kg/m^2/100 years; approximately 1/10 of the

deposition rate of Unit B (Table 7.15). It is considered that increased seasonal rainfall at Bandangala 1 appears to have resulted in the scouring of the older Unit A sediments in the northeastern side of the excavation, followed by accumulation of late Holocene Unit B sediments.

On the basis of the stratigraphy and radiocarbon determinations it appears that the Unit A sediments constitute the original site deposit. From around 2,000 years ago these sediments were scoured along the north and eastern sides of the trench and infilled by Unit B sediments. This scouring appears to correspond strongly with the orientation of the site with respect to Musselbrook Creek presumably from enhanced flooding events in the past.

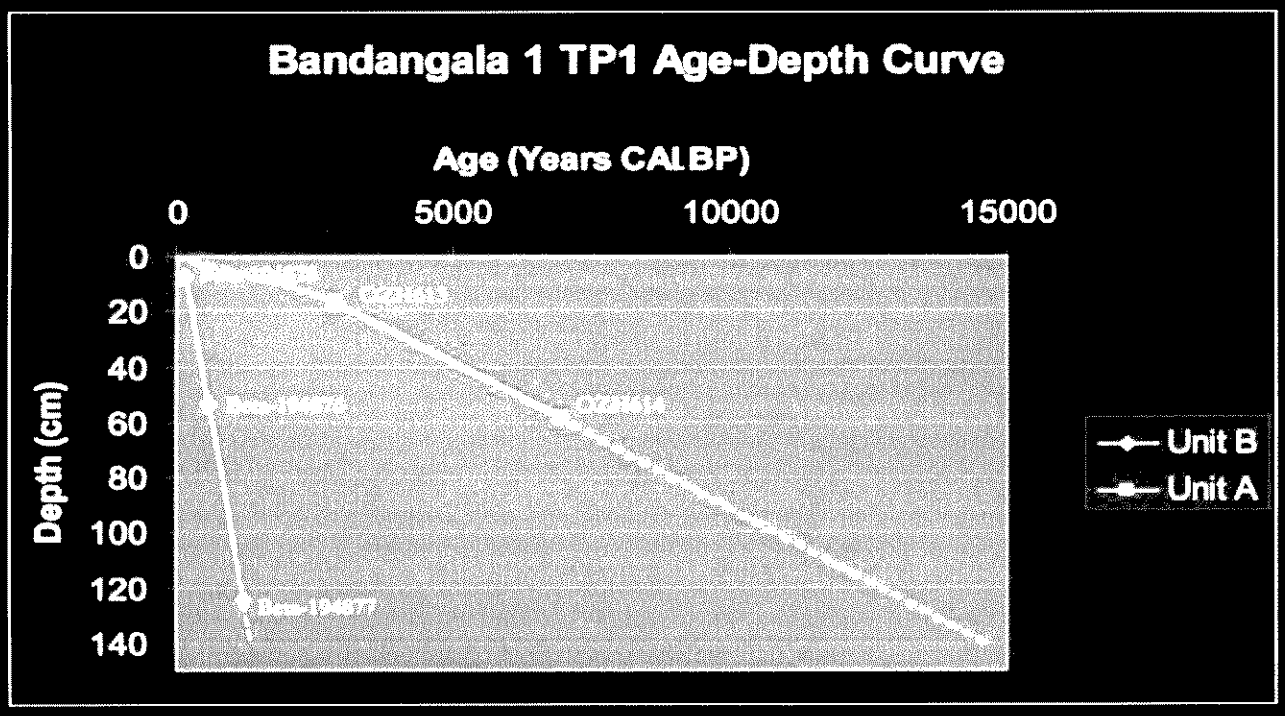

Figure 7.19: Age-depth curve for units A and B, Bandangala 1 testpit 1, Musselbrook Creek, northwest Queensland showing the differential rates of deposition for each unit and extrapolated basal dates.

Spit	Age of each Spit (cal BP)		Time Span		Sediment Deposition kg/m²/100yrs	
	A	B	A	B	A	B
1	-	38	-	38	-	63.16
2	-	150	-	112	-	43.21
3	-	200	-	50	-	165.00
4	2874	240	-	40	-	175.35
5	3456	299	583	60	12.01	117.30
6	3942	349	486	50	15.17	148.57
7	4476	404	534	55	13.10	127.94
8	4962	453	486	50	13.59	132.93
9	5399	498	437	45	14.71	143.60
10	5982	557	583	60	10.56	103.17
11	6468	607	486	50	14.82	117.80
12	6954	650	487	43	13.83	167.59
13	*7451*	693	*497*	43	*13.33*	152.68
14	*7948*	737	*497*	43	*13.08*	149.74
15	*8445*	780	*497*	43	*12.61*	144.34
16	*9042*	832	*596*	52	*9.61*	109.31
17	*9638*	883	*596*	52	*9.78*	111.88
18	*10036*	918	*398*	35	*14.20*	183.26
19	*11030*	1004	*994*	86	*8.90*	95.68
20	*11527*	1048	*497*	43	*14.59*	154.32
21	*11924*	1082	*398*	35	*18.86*	200.62
22	*12521*	1134	*596*	52	*18.53*	128.60
23	*13515*	1220	*994*	86	*16.95*	114.20
24	*14608*	1315	*1093*	95	*17.38*	117.85

Table 7.15: Sediment accumulation rates for Bandangala 1 TP1, Musselbrook Creek, northwest Queensland. Both Units A and B are shown. Accumulation rates for the lower Unit A spits are based on age-depth curves and are shown in italics.

Depositional sequences at Bandangala 1

On the basis of the radiocarbon determinations, sedimentation rates, and stratigraphy the Bandangala 1 TP 1 deposit has been divided into four analytical phases (Table 7.16). Phase A consists of the period between initial occupation of the site at about 13,000 cal BP and the beginning of the Holocene. It encompasses the lowest spits (18 - 24). The second phase (phase B) consists of those sediments dated to between 10,000 cal BP and 5,500 cal BP. This consists of spits 10 - 17 of the deposit. Phase C covers the period between 5,500 and 2,000 Cal BP (spits 4 - 9). Phase D is comprised of the upper spits 1 - 3 and provides a record for the last 2,000 years.

	Spits	Age Range
Phase A	18 - 24	10,000 - 13,000
Phase B	10 - 17	5,500 - 10,000
Phase C	4 - 9	2,000 - 5,000
Phase D	1 - 8	0 - 2,000

Table 7.16: Analytical units used for analysis of Bandangala 1 TP1 deposit, Musselbrook Creek, northwest Queensland.

TP1 Flaked Stone Assemblage

A total of 918 flaked stone artefacts have been identified from Bandangala 1 TP1. Few artefacts were recorded within the Unit B sediments (n= 161), and were mostly concentrated in the southern quadrant of the testpit in spits 2, 3 and 4 immediately overlying the Unit A sediments. It is possible that that the spit 4 material might originate from the interface with of Unit A.

The abundance of flaked stone artefacts changes greatly through time (Table 7.17). During the earliest phase of occupation between 13,000 Cal BP and 10,000 Cal BP discard rates are low (n = 30). Phase A contains just 1 core and 29 unmodified flakes. In contrast, phase B sediments feature much higher discard rates (n = 313) and a greater richness and variation in the assemblage, including 8 cores and 4 retouched flakes. Phase C also has a high discard rate in terms of weight of sediment, and as a measure of sediment volume. As with phase B, all classes of artefacts are present in the phase C including four backed artefacts. Due to the scouring of the upper sediments of Unit A, phase D sediment within stratigraphic Unit B features much lower discard (n=21) including 2 cores recorded just below the surface of the testpit and one retouched flake.

Although the quantity of flaked stone discarded for the Unit A sediments is very low (approx. 0.2 per 100 years), discard rates increase through time. This trend is not reflected however in measures of average weight of flaked stone through time. Average weights group by phases in general way; phase A spits 17, 18, 21- 23 are all very low, phase B and D weights appear to have no trend and are variable, whereas phase C spits 5 - 9 are grouped at approximately 1.5 g in the middle of the total sample range.

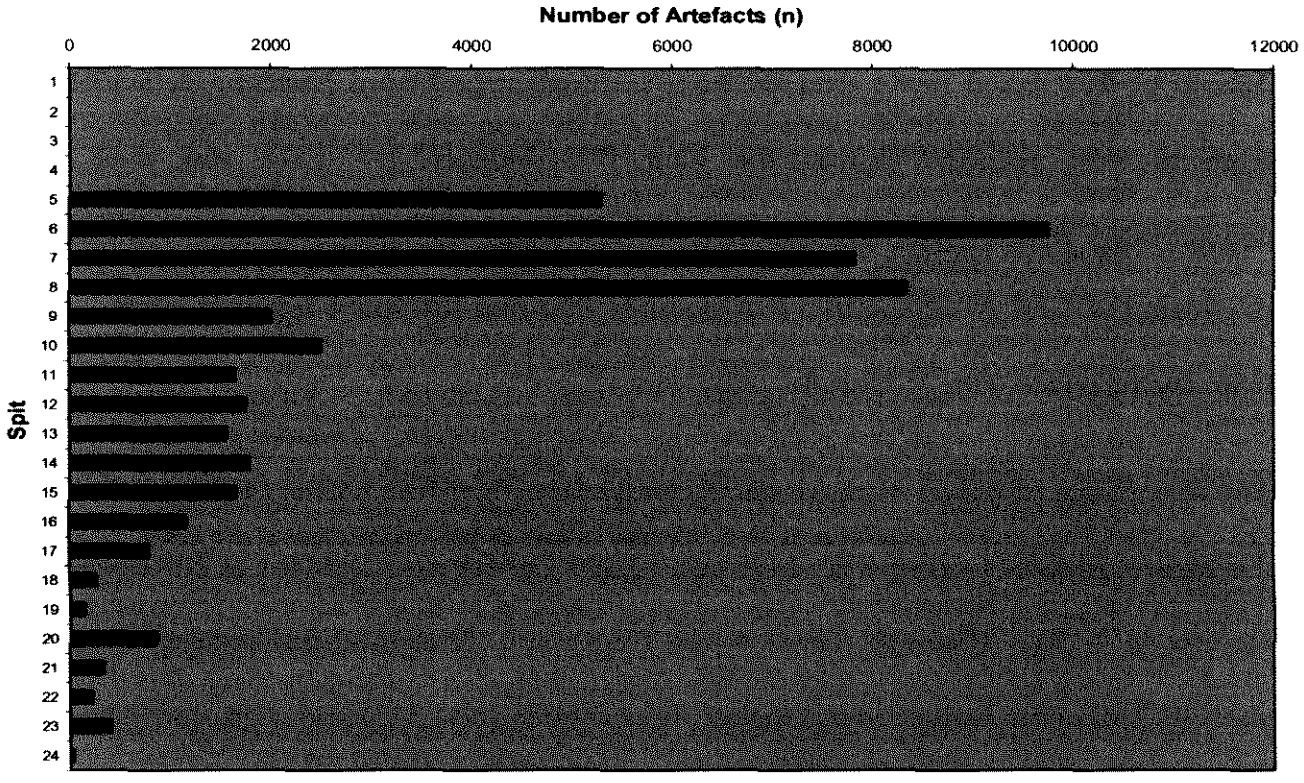

Figure 7.20: Bandangala 1 TP1 lithic assemblage for Unit A sediments showing number of artefacts discarded/m³.

Spit	Analytical Units Present	Volume		number of artefacts		number / kg		number artefacts / m³		number / 100 years		total weight (g)	average weight (g)
		A	B	A	B	A	B	A	B	A	B		
1	B	-	0.018	-	3	-	0.13	-	171	-	0.079	0.9	0.30
2	B	-	0.051	-	24	-	0.50	-	471	-	0.214	34.7	1.45
3	B	-	0.053	-	20	-	0.24	-	381	-	0.400	18	0.90
4	B	-	0.046	-	28	-	0.40	-	605	-	0.705	13.5*	0.05
5	A / B	0.007	0.040	37	11	5.29	0.17	5286	275	0.063	0.185	74.5	1.55
6	A / B	0.008	0.048	78	16	7.06	0.26	9750	333	0.161	0.322	136.1	1.45
7	A / B	0.011	0.038	86	13	6.14	0.23	7818	342	0.161	0.238	140.4	1.42
8	A / B	0.012	0.044	100	8	6.01	0.16	8333	182	0.206	0.161	151.8	1.41
9	A / B	0.015	0.035	30	3	1.67	0.06	2000	86	0.069	0.067	39	1.18
10	A / B	0.016	0.032	40	6	2.03	0.14	2500	188	0.069	0.101	64.8	1.41
11	A / B	0.023	0.028	37	5	1.28	0.14	1644	182	0.076	0.101	35.5	0.85
12	A / B	0.024	0.026	42	4	1.25	0.11	1750	154	0.086	0.093	76.5	1.66
13	A / B	0.025	0.023	39	8	1.11	0.26	1560	348	0.078	0.185	97.5	2.07
14	A / B	0.036	0.017	64	8	1.45	0.39	1778	471	0.129	0.185	74	1.03
15	A / B	0.042	0.008	69	1	1.33	0.09	1643	125	0.139	0.023	87.5	1.25
16	A / B	0.051	0.009	59	1	1.21	0.12	1157	111	0.099	0.019	87.9	1.47
17	A / B	0.046	0.007	36	1	0.73	0.11	783	143	0.060	0.019	13.7	0.37
18	A / B	0.042	0.005	11	1	0.23	0.11	262	200	0.028	0.029	1.1	0.09
19	A / B	0.021	0.004	3	-	0.17	-	143	0	0.003	-	8.5	2.83
20	A / B	0.007	0.003	6	-	0.41	-	857	0	0.012	-	8	1.33
21	A / B	0.009	0.003	3	-	0.20	-	333	0	0.008	-	0.2	0.07
22	A / B	0.014	0.001	3	-	0.14	-	214	0	0.005	-	0.3	0.10
23	A / B	0.024	0.001	2	-	0.06	-	83	0	0.002	-	0.3	0.15
24	A / B	0.027	0.001	12	-	0.32	-	444	0	0.011	-	28.9	2.40

* excludes one 216.6g hammerstone #Unit A only

Table 7.17: Summary lithic data for Bandangala 1 TP1, Musselbrook Creek, northwest Queensland.

Stone Raw Material

Eighty eight percent of the total assemblage from Bandangala 1 consists of chert, which has either been sourced from cobbles along Musselbrook Creek or brought from more distant sources. Other raw materials in the deposit include quartzite (7.3%), silcrete (3.5%) and single instances of greywacke and quartz. The discard rates of different raw materials mirrors the trends of overall lithic discard with the highest rates of non-chert discard occurring during the phase C spits 7 - 9.

Stone raw material richness of the Bandangala 1 deposit is restricted to six raw materials. The earliest phase of the deposit features chert and one isolated quartzite flake. Phase B features three raw materials. It is still dominated by chert however, quartzite frequency is higher, and there is a single example of a silcrete flake. Raw material richness is greatest in phase C sediments (5,500 - 2,000 Cal BP). During this phase all six raw materials are present with an increasing frequency of silcrete. During the upper phase D spits however, raw material richness declines to just three materials and is dominated once more by chert.

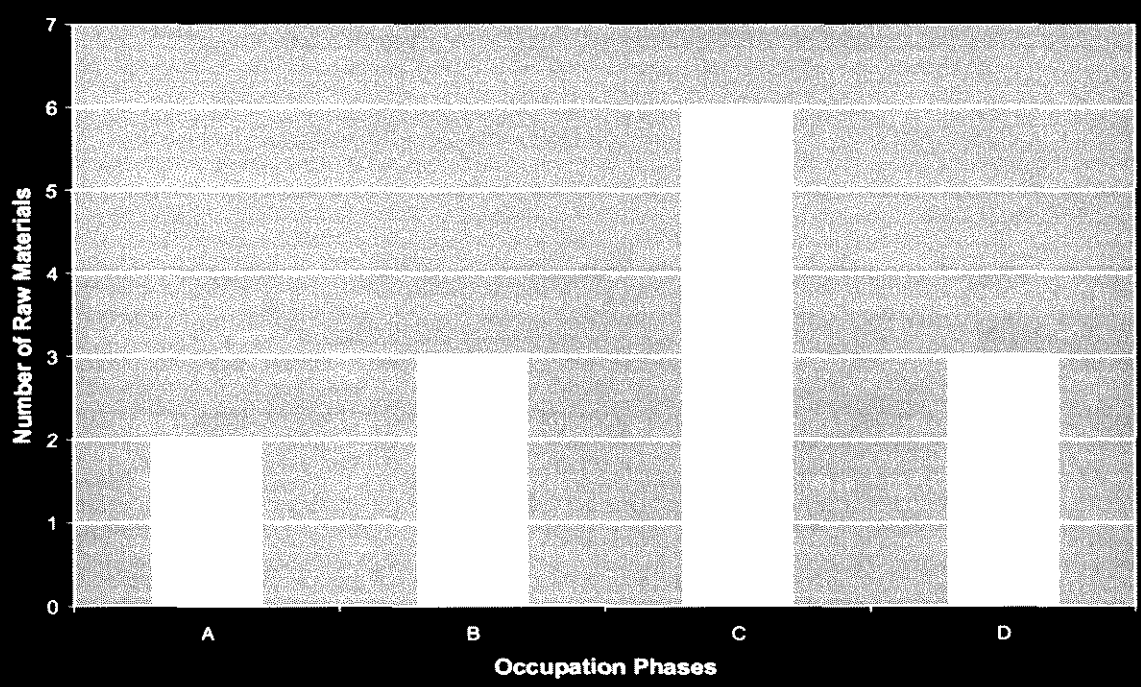

Figure 7.21: Stone raw material richness by phases for Bandangala 1 TP1, Musselbrook Creek, northwest Queensland.

Technological Change

Breakage

Breakage rates include transverse and longitudinal breaks, which have been separated into proximal, medial, distal and marginal transverse fragments, and into proximal, distal and 'complete' longitudinal fragments. The rate of breakage in flakes at Bandangala 1 is low and generally accounts for 22 - 28% of the assemblage (Table 7.18). During phase B breakage is less than 30% of the rate observed in other phases. Broken flakes are dominated by distal and proximal flakes. In all but phase B distal flakes are at least twice as frequent as proximal flakes, whereas phase B features an almost 1:1 ratio. This is thought to be due to re-use of proximal flakes.

%	Phase A	Phase B	Phase C	Phase D
broken flakes	28.21	7.16	28.12	22.73
proximal fragments	9.09	18.87	3.45	7.69
distal fragments	20.51	18.51	20.95	13.63
longitudinally cone split fragments	-	3.7	1.85	-
Ratio of transverse to longitudinal breakage	-	6:01	14:01	-

Table 7.18: Flake breakage in Bandangala 1 TP1, Musselbrook Creek, northwest Queensland.

The ratio of transverse breakage relative to complete flakes has been used as an indicator of the intensity of the site use of Bandangala 1. Comparison of this ratio with sediment accumulation rates for the deposit are presented in Figure 7.22. As for GRE8, it is predicted that there will be an inverse relationship between the ratio of transverse to complete flakes, to sedimentation. If this relationship does not hold then an increase in site use is inferred. Figure 7.22 shows that this relationship is true for phases A, B, and D, but during phase C the ratio of transverse to complete flakes compared to sediment

accumulation is very high. It appears that Bandangala 1 was more intensively occupied between 5,500 - 2,000 Cal BP.

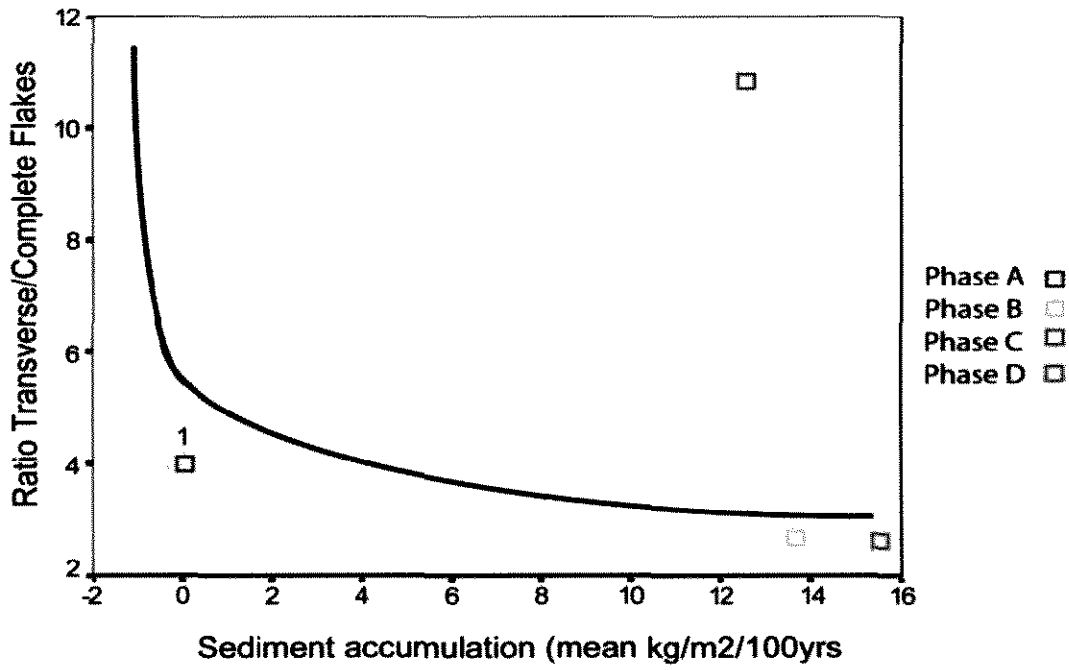

Figure 7.22: Ratio of transversely broken and complete flakes to sedimentation rates for Bandangala 1 TP1, Musselbrook Creek, northwest Queensland.

Knapping and reduction

Core reduction

Eleven cores were recorded from TP1. This included ten chert cores and one quartzite; all of which had between one and three rotations. Cores were only recorded for phase C (n=6) and phase B (n=5). All of the cores were small with a mean block volume of 9.23 cm^3 (S.D. = 3.06 cm^3), weight of 14.85 g (S.D. = 7.85 g) and averaged 8.66 flake scars (range was between 2 and 20). The length of the longest complete scar was 17.33 mm on average (S.D. = 5.82 mm).

Flakes

All flakes in the assemblage were produced using direct percussion, and no evidence of pressure flaking or indirect percussion was observed. Metrical examination of the location and force of blows to cores and flake platforms, the nature of core maintenance, and decortation processes was completed to assess reduction.

The majority of complete flakes possess no cortex, which is consistent with the presence of small flakes in the assemblage. Flakes with no cortex are greatest during phase D (the last 2,000 years). During phases B and C there is more variation in the percentage of dorsal cortex which is consistent with flakes from different stages of reduction. This result indicates that a range of knapping activities took place on site.

Amount of Cortex %	Phase A	Phase B	Phase C	Phase D
0 cortex	76.69	62.9	69.82	90.47
< 25%	3.33	12.78	8.58	4.76
26-50%	3.33	5.11	5.5	0
51-75%	6.66	6.09	3.4	0
76-99%	3.33	5.11	4.8	0
100%	6.66	8.01	7.9	4.76
number of flakes	30	313	291	21

Table 7.19: Changes in the amount of cortex on flakes in Bandangala 1 TP1, Musselbrook Creek, northwest Queensland.

Applied Force

The extent and precision of the force applied, when flaking stone, can indicate whether the reduction of stone raw materials involved techniques that conserved material and reduced stone carefully. Flake termination type, the prevalence of shattered surfaces, and the area of flake ventral surfaces were recorded. Figure 7.23 details a box plot of the average ventral surface area of complete flakes for each spit of Bandangala TP1. Flake area is generally less than 4 cm^2 but can be as large as 7 cm^2 and is considered to primarily reflect the morphology of cores. Ventral surface area comparison does indicate that flake size in spits 1 - 6 is much smaller than in older levels. This may be because there was greater artefact reduction in the recent spits and the application of force was less and more controlled. It might also be due to taphonomic reasons as these spits are chiefly comprised of Unit B recent sediments.

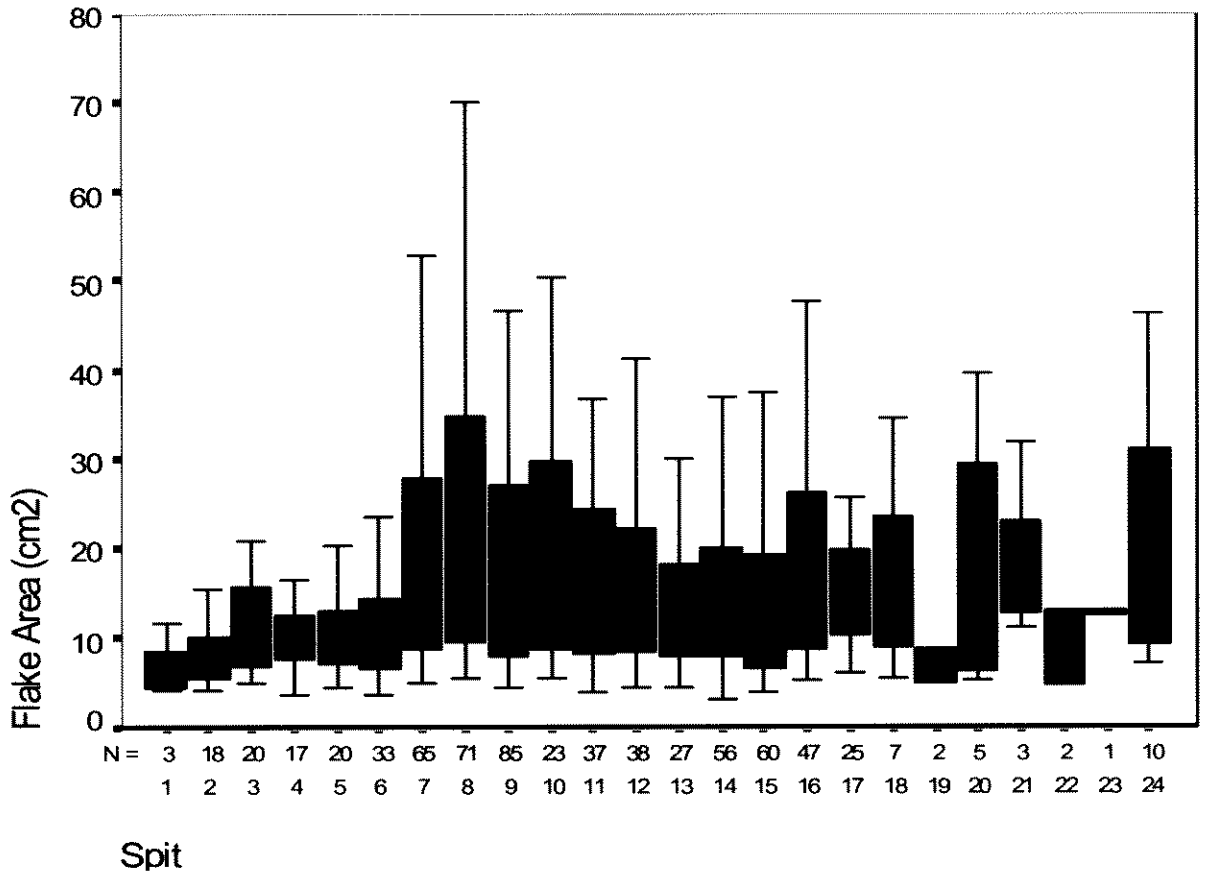

Figure 7.23: Box plot graph of average flake size in cm^2 for Bandangala 1 TP1, Musselbrook Creek, northwest Queensland. Red areas indicate upper and lower quartiles middle 50% of data, black line is median, whiskers indicate remaining quartiles.

The range of termination types present on complete flakes is presented in Table 7.20. Aberrant terminations occur consistently throughout the deposit, being slightly lower during phase C (5,500 - 2,000 BP).

	Phase A	Phase B	Phase C	Phase D
Feather/axial	86.7	84.3	88.7	86.7
Hinge	13.3	9.1	5.8	13.3
Step	-	6.1	5.2	-
Outré passé	-	0.5	0.3	-
n	30	313	291	21

Table 7.20: Relative percentages of different termination types for the analytical units of Bandangala 1 TP, Musselbrook Creek, northwest Queensland.

Location of the Force of Application

Two measures of knapping force have been used in analysis of the Bandangala 1 TP1 assemblage: the type of platform surface to which the blow is made, and the proximity of the blow to the core edge. The assemblage is dominated by platforms on a single flake scar (77 - 91%) with no evidence for faceting or grinding. Unprepared cortical platforms consistently account for 9 - 14% of the assemblage. During recent phases, particularly phases C and D there is greater variation in platform types including an increase in the frequency of platforms created on multiple flake scar surfaces (Table 7.21).

Platform Types	Phase A	Phase B	Phase C	Phase D
indeterminate	-	0.3	0.66	-
cortical	9.09	11	14.8	11.63
single flake	90.91	84.71	77.3	79.07
multiple flake	-	3.99	6.9	4.6
shattered	-	-	0.34	4.6
total number	33	327	304	43

Table 7.21: Relative percentages of platform types by percentage for the Bandangala 1 TP1, Musselbrook Creek, northwest Queensland.

The width of flake platforms perpendicular to bulbar scars was used as a measure of the placement of blows and intensity of force with respect to the core face. At Bandangala 1 this analysis shows that platform size is generally small (~ 3 mm). During phase B it increased to 3.62 mm and in phase D platform thickness is smallest at 2.56 mm. This data is consistent with trends observed in flake ventral surface area.

The frequency of overhang removal from core platforms prior to flake removal shows a steady increase through time. In phase A just 3% of flakes feature overhang removal, whereas in phase D this rate rises to over 13%. This may represent attempts to conserve raw materials, and if so, indicates that access to such materials during the last 5,000 years was more restricted here than other sites.

Platform Features	Phase A	Phase B	Phase C	Phase D
% flakes with overhang removal	3.03	5.18	5.46	13.04
average platform thickness (mm)	3.07	3.62	3.12	2.56
n	33	341	311	43

Table 7.22: Platform features by phase recorded for the Bandangala 1 TP1, Musselbrook Creek, northwest Queensland.

Comparison of the average length to width of all complete flakes shows increasing elongation through time. Flakes from the lowest two phases are very small with a length to width ratio of 0.8:1, whereas by spits 5 - 7 this ratio is over 1.2:1 (Figure 7.24).

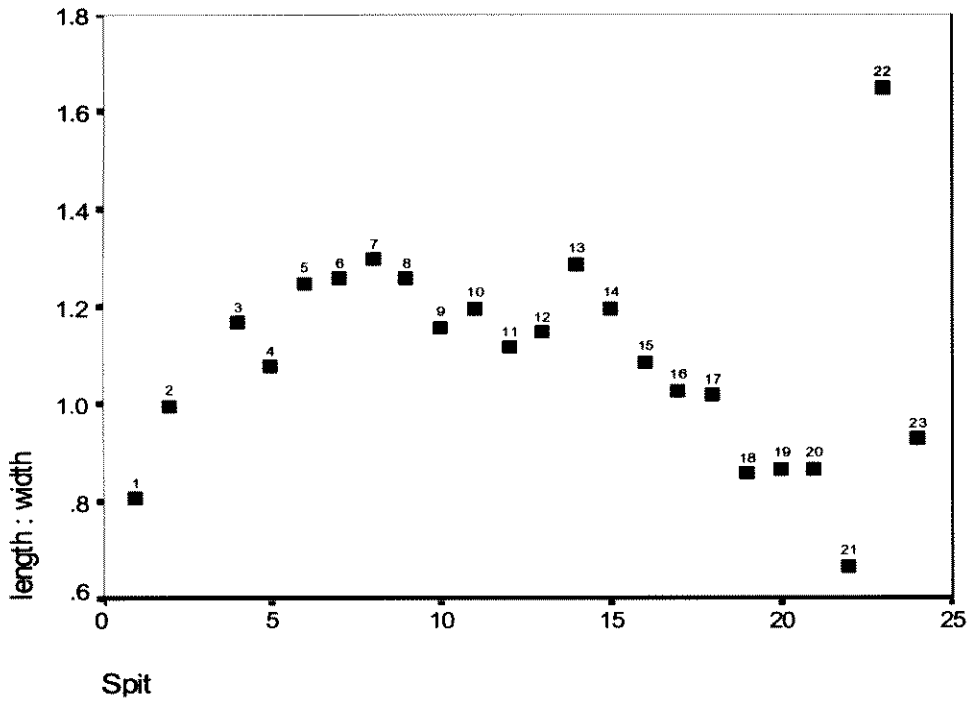

Figure 7.24: Ratio of average proximal length to average proximal width of complete flakes by spit for Bandangala 1 TP1, Musselbrook Creek, Lawn Hill.

Retouched Flakes

Seventeen retouched flakes were recovered from the excavated sample. All were produced from chert and are characterised by amorphous retouch (n=10). There are five unifacial points and two tulas in the assemblage, occurring in phase B and C, between 10,000 and 2,000 Cal BP. Most of these occur in phase C (5,500 - 2,000 Cal BP) (n=6) and correspond with increased regional aridity, and might therefore be a technological response to increased resource patchiness.

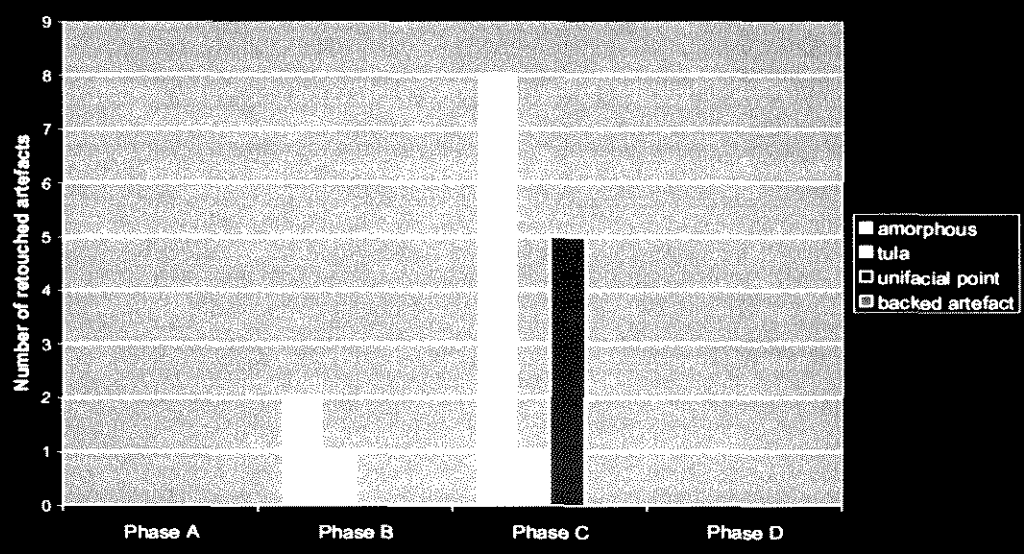

Figure 7.25: Retouched artefacts (n) for each analytical phase in Bandangala 1 TP1 deposit, Musselbrook Creek, northwest Queensland.

Faunal Assemblages

The faunal assemblage at Bandangala 1 includes both terrestrial and riverine species, with small and medium macropods, turtle, fish, and fresh water mussels. A total of 4,906 fragments of bone were recovered. As with other sites excavated in this project, bones that could not be identified to species were attributed to a size range: 'large mammal' (cf. *Macropus rufus/Macropus giganteus* size), 'medium mammal' (cf. *Macropus eugenii/Trichosurus vulpecular* size) and 'other' the bone fragment was unable to be identified to element.

The relative percentage composition of each fauna type has been calculated for the Bandangala 1 TP1 deposit. This shows a general decline in the quantity of large and medium sized fauna in the site by over 50% over the occupation of the site. This drop is particularly evident in phase C (5,500 - 2,000 Cal BP) and coincides with increases in the relative abundance of small mammals (Figure 7.26).

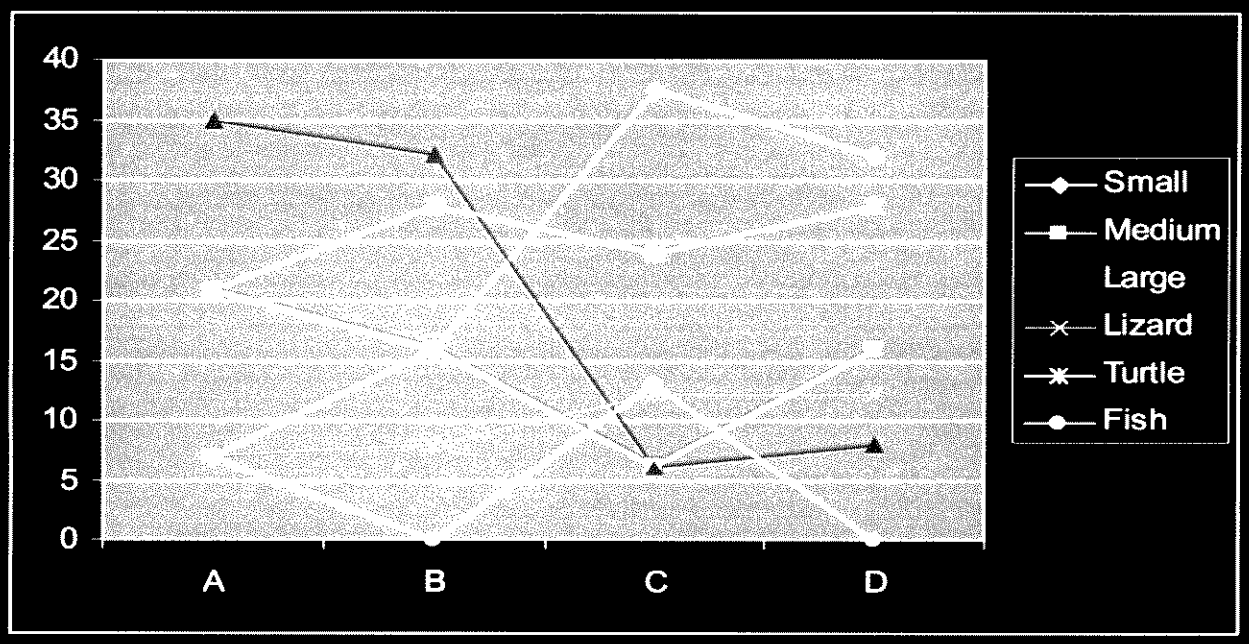

Figure 7.26: The percentage abundance of bone by fauna type in Bandangala 1 TP1, Musselbrook Creek, northwest Queensland.

The frequency of bone fragments for Bandangala 1 TP1 indicates a high accumulation rate in spits 7, 8 and 9 (n=974 in spit 8), a constant rate (between 200 - 400 fragments) for most other spits, and very low frequencies for spit 17 and below. This data is expressed as weight per cubic metre of sediment (Figure 7.27).

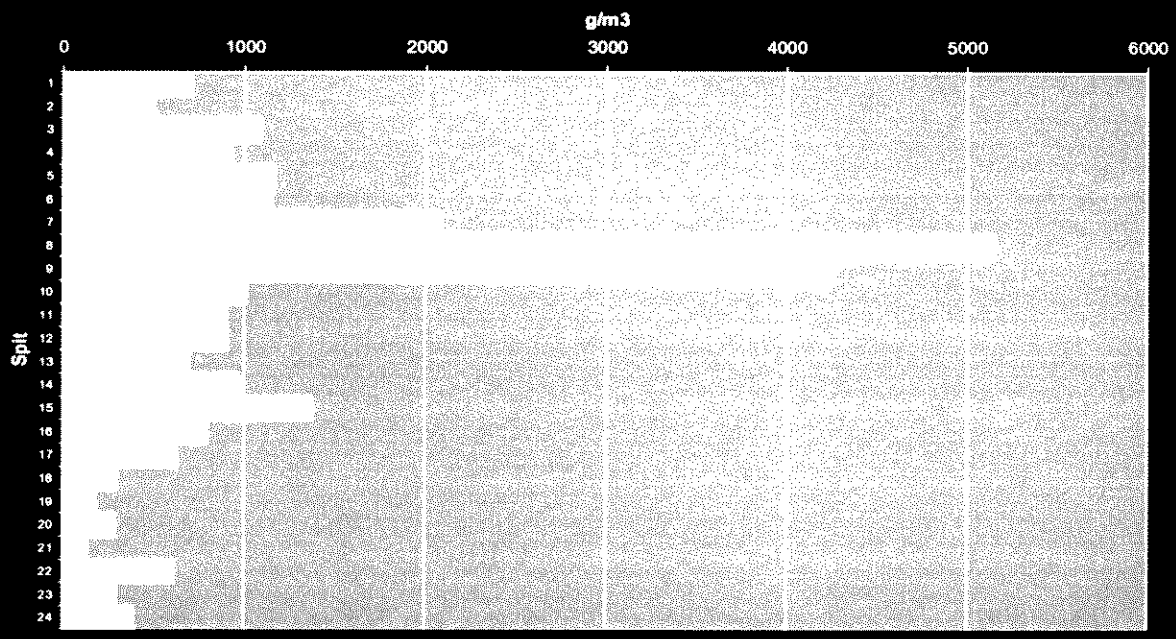

Figure 7.27: Changes in abundance of vertebrate fauna weight by spit/m³ in Bandangala 1 TP1, Musselbrook Creek, northwest Queensland.

Invertebrate Fauna

The invertebrate fauna at Bandangala 1 consists of freshwater mussels *Alathyria pertexta spp.*, and *Velesunio sp.* plus low numbers of turtle, mollusca, crustacea, and fish (perch and catfish). The Unit A sediments yielded very few remains whilst shell density is very high in the younger Unit B sediments (Figure 7.28). Possible mechanisms include human discard, and natural occurrence as the result of scouring and flooding events in Musselbrook Creek.

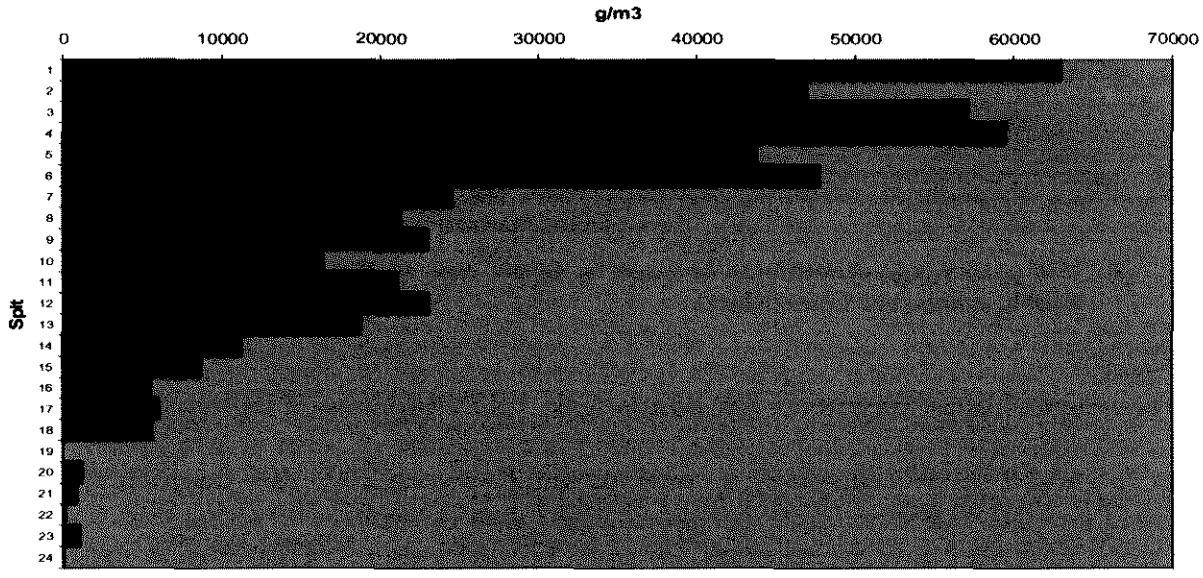

Figure 7.28: Frequency of mussel shell expressed as g/m³ by spit for Bandangala 1 TP1, Musselbrook Creek, Lawn Hill.

Summary

There are notably consistent trends in the discard of both flaked stone and faunal material in the Bandangala 1 deposit. Bandangala 1 was first occupied c. 13,000 Cal BP (based on the age-depth curve) and has been regularly visited until recent times. The assemblages at Bandangala 1 show diversity in stone raw materials that are not present in the more southern sites. The flaking techniques are consistent with other sites of similar antiquity, that is in their focus on producing expedient tools. The flaked stone artefact assemblage from Bandangala 1 TP1 displays a steady change in most attributes through time. Discard

rates, raw material diversity, retouch, diversity of platform types and the occurrence of overhang removal all increase in relative frequency through time. Analysis of the flaked stone assemblage shows that during phase C the site was more intensively utilised than at any other times. Between 5,500 and 2,000 Cal BP the rates of fragmentation relative to sedimentation are also far greater than during any other phase. This phase also features the highest rates of discard, variation in the extent of reduction and raw material richness. This period also corresponds with the highest frequency of faunal discard and an apparent change from large mammal to small mammal consumption.

The composition of the flaked stone assemblage indicates that the population which inhabited the Bandangala area within Musselbrook Gorge had a relatively localised subsistence system, exploiting nearby resources until the conclusion of the mid-Holocene El-Nino period of enhanced aridity. After this time the Bandangala 1 site was visited more intensively, and features lithic raw materials from more distant sources plus greater levels of reduction. This is interpreted as an expansion in foraging area and changes in stone procurement strategies.

Over the last 2,000 years sediments have been scoured by flooding followed by further sediment accumulation, which has created the Unit B sediments. Sediment accumulation is also evident at raised levees associated with freshwater creeks running into the Musselbrook Creek sandstone gorge. The rapid build up of sediment during the late Holocene has been most likely associated with increased local precipitation after the extreme El Niño/Southern Oscillation (ENSO) cycles of the mid to late Holocene in northern Australia which diminished around 2,000 BP (Hope and Golson 1995; Kershaw 1995; McCarthy and Head 2001). Increased local rainfall led to seasonal inundation of Musselbrook Creek since c. 1,000 BP (see Schulmeister and Lees 1992). It is likely that flooding has resulted in rapid sediment deposition in levees along the creeks in all local

sandstone gorges, as seen at Bandangala 1. A reconfiguration of Aboriginal settlement of this area my have followed the amelioration of ENSO conditions after 2,500 Cal BP as larger permanent water supplies became available and subsequent use of the Bandangala 1 site decreased.

7.4 Elizabeth Creek

7.4.1 AL:B37

Site Setting

AL:B37 rockshelter is located in a group of sandstone outliers that forms part of an extensive escarpment along Elizabeth Creek in the north of the study region. The rockshelter occurs approximately 500 m from the permanent water of Elizabeth Creek, and 50 m from the edge of the eastern plains. Its position means that any travel through the area would entail passing here. The site is located near five small sandstone boulder stacks that outcrop on the side of the hill. Some of these stacks feature large flat sandstone surfaces suitable for art, and three art sites are known within 50 m of AL:B37.

The local vegetation community at ALB:37 consists of patches of grasslands with a raised plateau devoid of any vegetation located directly behind the site. As Musselbrook Creek is nearby, woodlands extend up to a distance of 400 m from the site. Elizabeth Creek is a seasonal but extensive creek and during the wet season it is about 50 m wide near to AL:B37. During the dry season the creek is reduced to a series of waterholes each up to 500 m in length. As such, there is a general absence of fringing and riparian vegetation, with the woodlands community extending to the riverbank.

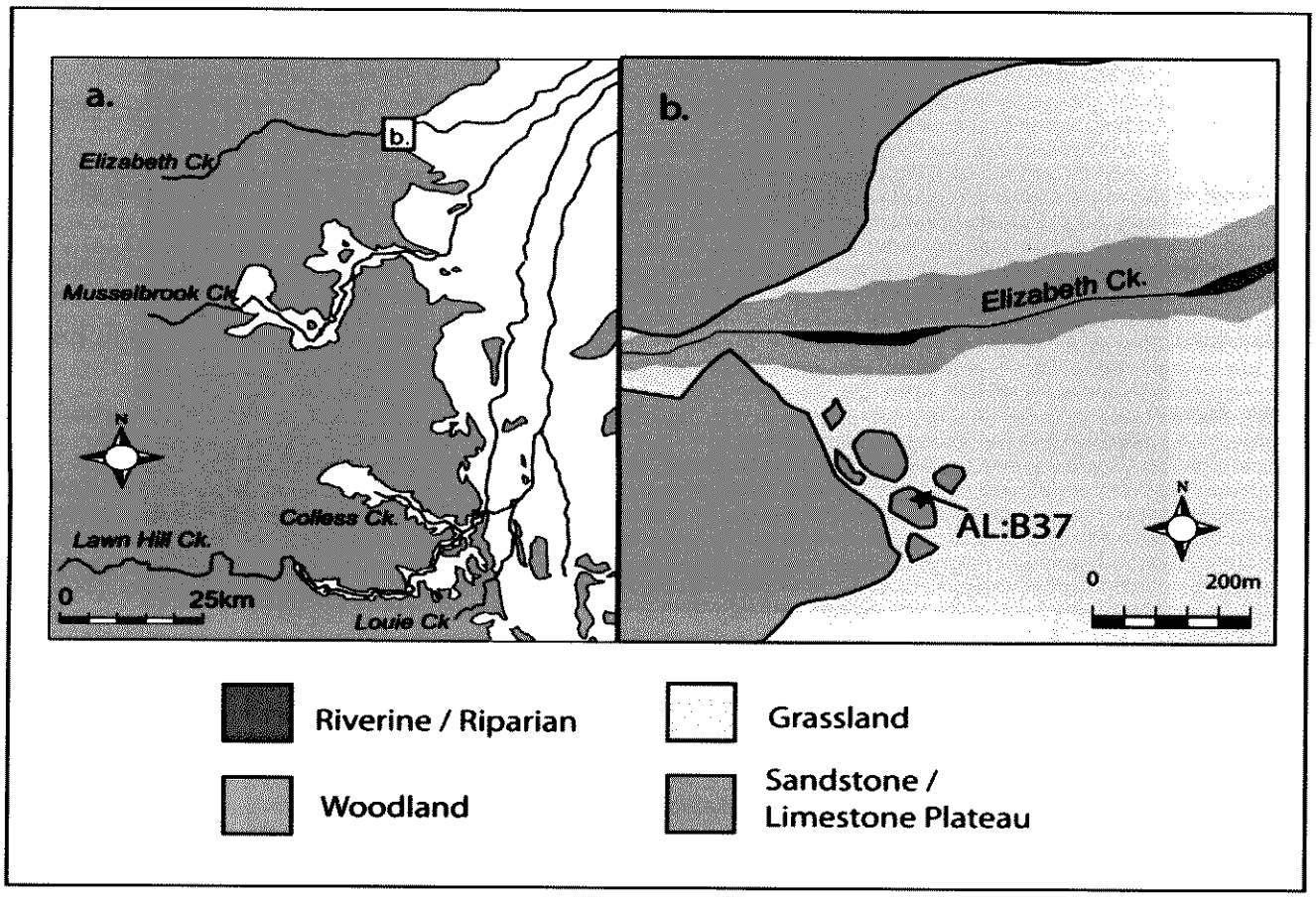

Figure 7.29: Location of AL:37, Elizabeth Creek, northwest Queensland. A. shows the general location of the area marked as b. B. details the location of AL:B37 and its relationship to local patch types.

Site Description

AL:B37 is a small rockshelter formed on the eastern side of one of the sandstone mesa. The dripline of the shelter is about 10 m above ground surface and the wall of the shelter is comprised of near vertical flat sandstone. The AL:B37 site features the second largest panel of rock art known for the region, and the most complicated array of motifs and techniques. Art covers an area approximately 8 m long and 3 m high, and consists mostly of freehand paintings including bichrome rainbow designs in red and yellow, and monochrome figurative images that have been described as various objects (crocodiles, people, and coolomons) (see Border 1989).

Figure 7.30: AL:B37 site in the background and local vegetation, Elizabeth Creek, northwest Queensland.

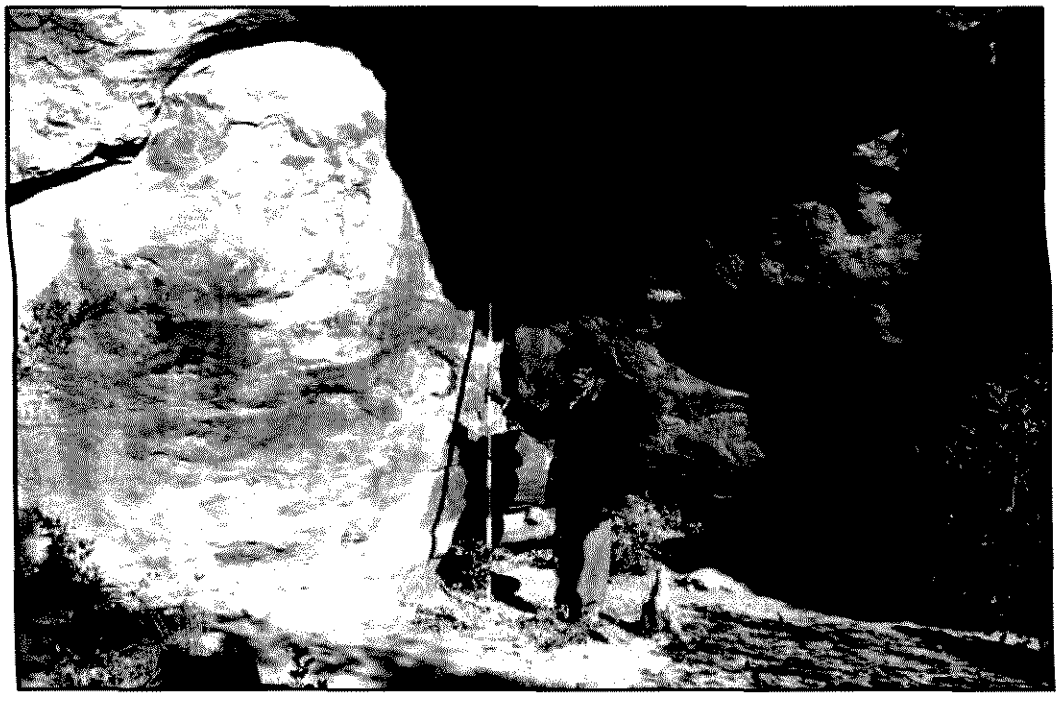

Figure 7.31: AL:B37 with Richard Brookdale holding a scale in front of the extensive rock art panel, Elizabeth Creek, northwest Queensland.

Excavations

In 2003 a 50 cm x 50 cm test pit was excavated in a position near to the northern end of the shelter (Figure 7.32). The site was excavated in 5 cm spits through unconsolidated sandy sediment to weathered bedrock c. 30 cm below the surface. Further excavation of a remaining section of the trench reached a maximum depth of 50 cm. All excavated sediments were weighed, sieved and sorted on site. Analysis of lithic material was completed at the University of Sydney.

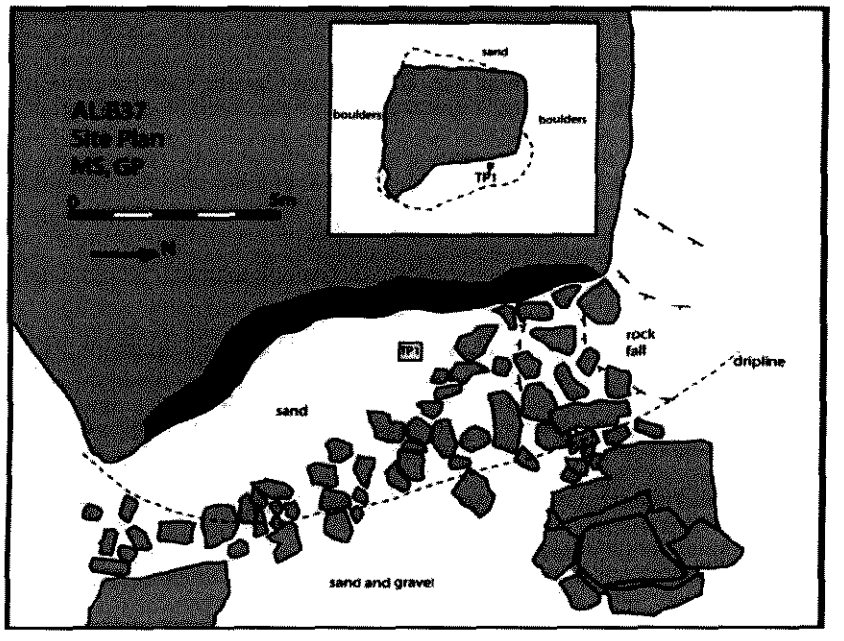

Figure 7.32: AL:B37 rockshelter showing location of test pit and extent of the rock art panel, Elizabeth Creek, northwest Queensland.

Stratigraphy

Two stratigraphic units were identified at AL:B37: Unit A (8 – 30 cm) is comprised of fine sandy orange/red sediment with very few finds recorded *in situ*. Unit B sediments (0 – 8 cm) consist of carbon rich grey/black sediment (Figure 7.33).

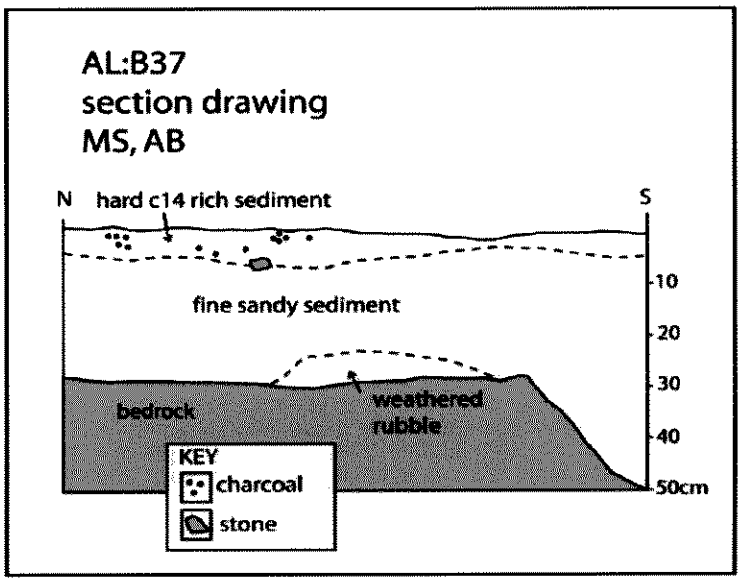

Figure 7.33: Section profile of the AL:B37 test pit, Elizabeth Creek, northwest Queensland.

Chronology

Three radiocarbon determinations were obtained for charcoal from the AL:B37 testpit 1 deposit (Table 7.23). Two different depositional episodes are indicated by the stratigraphy and C14 determinations for the site. Unit A sediments have accumulated quickly from about 1, 800 years ago. This might relate to the timing of the collapse of overhangs that have since trapped sediment in the site. This timing is also coincidental with increased rainfall after the amelioration of ENSO conditions c. 2,000 years ago. The Unit B sediment dated at 147 Cal BP record recent occupation of AL:B37.

ANSTO Code	Dating medium	$\delta(^{13}C)$ per mil	Percent Modern Carbon		Conventional 14C age		Calibrated Age (Cal BP) mean 2s.d
			pMC	1σ error	Yrs BP	1σ error	
OZH609	charcoal	-24.2	97.63	0.64	190	60	147.5
OZH610	charcoal	-25	78.07	0.42	1990	50	1864
OZH611	charcoal	-26.2	79.15	0.6	1880	60	1732

Table 7.23: Radiocarbon determinations for AL:B37, Elizabeth Creek, northwest Queensland.

Cultural Material

A total of 25 flaked stone artefacts, a surface find of one grindstone, 18 g of fragmented mussel shell, and 2.2 g of unidentified bone were recovered from AL:B37. The shell, bone and ochre-like material, charcoal and other organic material were recovered from the Unit B sediments. Unit A yielded only flaked stone artefacts.

The flaked stone assemblage consists of 25 artefacts (MNA). Eighty eight percent of this was comprised of unmodified flakes. Two amorphous retouched flakes were recovered from spit 2 (Unit B) and one chert core from in spit 4. The assemblage is primarily comprised of small quartz flakes (n=13) spread throughout Unit A with smaller numbers of chert (n=7), quartzite (n=4) clustering in Unit B (spit 2) (Table 7.24).

Spit	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**total**
Cores				1								1
retouched flakes		2										2
flakes (mnf)	1	6	2	2	2	4	1	1	1	1	1	22
Total												**25**

Table 7.24: Flaked stone assemblage of AL:B37 TP1, Elizabeth Creek, northwest Queensland.

Summary

The AL:B37 assemblage suggests only recent infrequent and transient visits to this site. During initial visits from about 1, 800 years ago lithic discard is comprised of only very small local quartz flakes. High frequencies of charcoal and higher rates of lithic and faunal remains found in the upper Unit B sediments represent the main occupation of the site.

These indicate that the site was visited more regularly from around 200 years ago, possibly earlier (further refinement of the radiocarbon chronology is required to confirm this). People visiting the site during this phase brought more distant raw materials with them, created fires within the shelter and most likely produced the extensive rock art panels.

7.5 Chapter Summary

This chapter has discussed the results of the extensions to the excavation program that included the Lawn Hill, Musselbrook and Elizabeth Creek areas of the research region. This northern region features a different settlement and subsistence strategy than was the case for the southern research area. Whilst Lawn Hill was first occupied sometime prior to the LGM the remainder of the northern region does not appear to have been settled until after the amelioration of aridity c. 13,000 Cal BP. By this time Lawn Hill had also been reoccupied following a period of abandonment c. 17,000 BP. Settlement appears to have focused initially on the most substantial of the northern water courses, Musselbrook Creek. It appears that subsistence strategies in this area were broad, using a variety of stone material, different artefact types, and acquiring a range of fauna. However, with the onset of El Nino aridity between c. 2, 000 and 5, 500 Cal. BP, a contraction in subsistence occurred. At Bandangala 1 people contracted their foraging range and diet breadth by focusing on smaller mammals and riverine resources.

After the amelioration of the aridity associated with the mid Holocene it appears that a further reconfiguration in the northern settlement system occurred. The intensity of occupation of Musselbrook Creek increased but with greater mobility, sites including Wild Dog Dreaming were occupied, and eventually even the more marginal patches where sites like AL:B37 on Elizabeth Creek were periodically visited.

The results of the excavations and analysis for these northern sites support the differential patch model presented earlier. It is clear that different strategies of settlement, resource procurement and technology occurred in the north compared to the south. This is considered to be primarily a product of variability in climate, causing uncertain rainfall, combined with a hydrology that is much less stable and does not support large free - standing pools of water (as the south does), thereby limiting the potential for aggregations of population.

Chapter 8

Between the Desert and the Gulf: Evolutionary Anthropology and Aboriginal Prehistory in the Riversleigh/Lawn Hill Region, Northern Australia.

8.1 A Model of settlement and subsistence for Riversleigh and Lawn Hill

The Riversleigh and Lawn Hill data has provided a rich record of human occupation of the Gulf of Carpentaria region and Australian prehistory. Using this data in combination with the theoretical framework of chapters 4 and 5 this chapter discusses the synthesis of this information. The following model of settlement and subsistence for the Riversleigh and Lawn Hill region is based on three sources: *(i)* the functional predictions of the HBE models; *(ii)* the known constants and constraints of the research area (resources); and *(iii)* the climatic changes of the last 40,000 years.

8.1.1 Resources

The Gulf of Carpentaria has a diverse array of arid and semi-arid landscapes; extensive salt flats, savannah woodlands, spinifex plains and large rocky outcrops. Through these environments run a series of permanent water courses, some of which are aquifer fed which have flowed at the same rate as today even during the height of the LGM. Economic resources clump around these areas, in the woodlands and riparian corridors, and would have provided a focus for human subsistence activities in the region.

The Riversleigh/Lawn Hill project was focused on three of the largest regional streams: the Gregory River, Lawn Hill Creek and Musselbrook Creek. Within the study area these rivers are transformed by the junction of the two primary geological units of northern Australia: the Gulf Plain and the Barkly Tableland. At Riversleigh and Lawn Hill this

junction has created extensive gorges containing numerous economically important resources. As such, settlement and subsistence strategies at Riversleigh and Lawn Hill are closely linked to the location of critical resources in the landscape and the structure of sites. These resources include permanent water, stone sources, and natural shelter.

(i) Distance to permanent water

Distance to permanent water has often been invoked as a primary constraint to human settlement (*cf.* Allen 1972; Gould 1977; Hiscock 1988; Smith 1988; Veth 1993), though in some cases the importance of this resource is arguably over-emphasized at the expense of other explanations for site location and structure (*cf.* Thorley 1998a). However, within the Riversleigh and Lawn Hill region the location of permanent and semi-permanent water is well mapped, and effectively mirrors the spatial patterning of hunter-gatherer occupation and subsistence activities. All of the major watercourses in the research area have remained relatively stable in their course and flow over the last 40,000 years. The only interruption to water flow has been the possible reduced flow of northern rivers and areas on the eastern plains during periods of increased aridity, seasonal discharges, and temporary tufa dam formations.

All sites of greater than 10,000 years BP that are known from this region have a close association with water and none are more than 2 km from the nearest river. All but one site (Gamanyi) are within 1 km of a permanent water source. When undated surface lithic assemblages are added to the database, over 80% of all sites are within 2 km of permanent water.

(ii) Distance from Knappable Stone Sources

The location of stone raw material sources is highly predictable for the research region. Chert is known to occur as cobbles in river and creek banks, and in limestone outcrops in

the western and southern Riversleigh plateau area. Greywacke features as exposures on the eastern plains, whilst silcrete and quartzite are more variable in their occurrence. At all sites investigated the dominant raw material used for flaked stone manufacture is chert.

(iii) Site Types

Natural shelter includes rockshelters and caves. Although it is very likely that hunter-gatherers also used temporary shelters made from plant materials, as noted in ethnographic observations (*cf.* Creaghe 1883), these are generally not preserved in the archaeological record. Middens and lithic scatters which are found within woodland and riverine patches along river systems may have had shelters associated with them.

Rockshelters occur primarily in the western area of the research region, within the limestone and sandstone gorges of the major water courses. Some shelters also occur on isolated mesa within the plains environment, and show signs of occupation in the form of lithic scatters and rock art (Border 1989; Hiscock 1986). Within the study area numerous rockshelters display evidence of occupation in the form of lithic material, middens, and rock art. Most sites with occupation debris are over 10 m^2 in floor area and at least 1.5 m in ceiling height. Many other shelters of similar dimensions have no visible signs of occupation, though may have witnessed periodic visits.

The configuration of water, stone sources and shelter in the Riversleigh and Lawn Hill research region presented good potential for exploring the application of the HBE approach to the archaeological record.

8.1.2 Site Location and Settlement at Riversleigh and Lawn Hill through time

In addition to the critical resources, settlement and subsistence has also been determined by the location and frequency of economic resources. The relationship between food and essential resources (i.e. water) has varied over the last 40,000 years, due primarily to climatic changes.

Occupation Periods

There are six climatic phases in the model of settlement and subsistence for Riversleigh and Lawn Hill (phases A - F). Phase A covers the initial settlement period of the region between *c.* 50,000 and 30,000 Cal BP. Phase B includes the period of climatic deterioration known as OIS2/the Last Glacial Maximum (LGM), between 30,000 and 18,000 Cal BP (see Lambeck and Chappell 2001). Phase C occurs between 18,000 and 10,000 BP, marking the final stages of the Pleistocene epoch when climatic conditions improved, though were still variable. Phase D, *c.* 10,000 - 5,500 Cal BP was warmer and wetter, roughly paralleling the modern day regional climate. Phase D features short periods of climatic instability - the Younger Dryas cold period at *c.* 10,300 BP and climatic flux associated with the El Nino southern oscillation (ENSO) *c.* 5,500 Cal BP. Phase E covers the enhanced El Nino arid period between 5,500 and 2,000 - 1,500 Cal BP, which was characterised by extensive arid/drought periods. Phase F comprises the recent past between 2,000 Cal BP and the present. For each of these different phases the nature of site location and settlement within the research region shows distinct patterning.

All of the sites presented in this thesis were dated by radiocarbon determinations on shell or charcoal. Chronologies were established using age-depth curves coupled with geomorphic and stratigraphic data. A summary graph of the chronology of occupation for

all sites within the research region, featuring the climatic phases, is shown below in Figure 8.1.

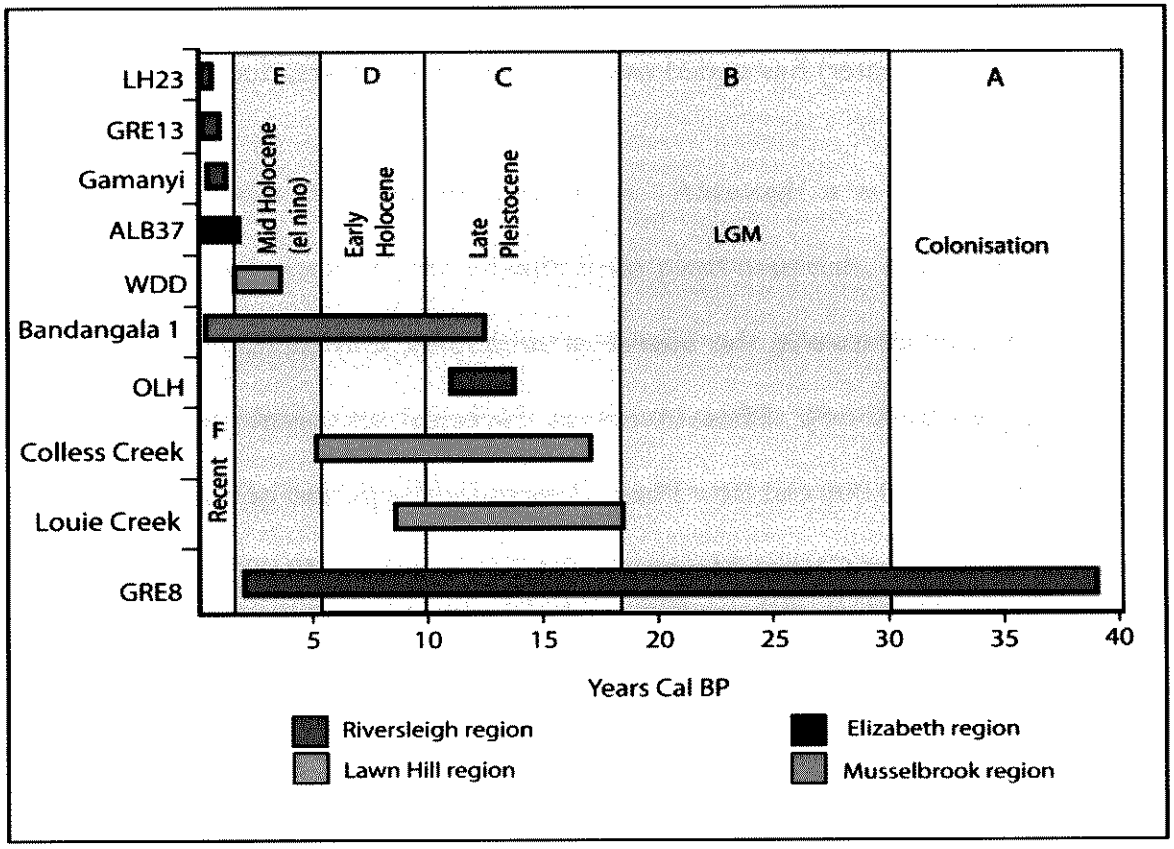

Figure 8.1: Chronologies of all excavated sites within the Riversleigh/Lawn Hill research region based on calibrated C14 dates and featuring climatic phases.

Phase A: colonisation and settlement (c. 50,000 – 30,000 Cal BP)

During the initial occupation phase, the climate of the research region was similar to that of today, although perhaps a little wetter (Lambeck 2002; Lambeck and Chappell 2001). The Australian mainland was joined to New Guinea, and the Gulf of Carpentaria was a huge fluctuating inland lake/gulf. All of the major river systems of the research region had permanent water flow and environmental patches would have been slightly more productive than today.

Occupation during phase A (50,000 - 30,000 Cal BP) is represented by the Gregory 8 (GRE8) rockshelter deposit at Riversleigh. During this phase, occupation evidence for

GRE8 comprises *c.* 80 flaked stone artefacts only. The lithic assemblage suggests that the site, and probably the wider Gregory River valley, featured a very low intensity of occupation. It is possible that the regional occupation included the northern river corridor of Lawn Hill Creek as the Unit A sediments (undated sediments below the site lag surface) at Colless Creek Cave are likely to span this period (Hiscock 1988).

The artefact assemblage during this phase at GRE8 consists primarily of locally available chert with marked variability in artefact size and weight. Perhaps founding populations, with little local knowledge were testing raw material properties and flaking characteristics, and occupation of the area was marked by infrequent visitation.

Phase B: Last Glacial Maximum (c. 30,000 – 18,000 Cal BP)

Between 30,000 and 18,000 Cal BP a period of sustained reduced temperatures and precipitation occurred. Low precipitation and consequent widespread aridity reduced the size of Lake Carpentaria, reduced river flows and limited the likelihood of any presence of ephemeral water. Severe droughts, high winds, and dust storms were common events in northwest Queensland over this period. The effect on the local environments in the study area would have been severe. Patch productivity and grain would have decreased substantially, and the low value grassland and spinifex patches expanded dramatically.

As with phase A, the LGM phase is represented by the ongoing occupation of GRE8, Riversleigh. At Lawn Hill, it appears that Colless Creek was abandoned sometime during either the previous phase or during the LGM as evidenced by the lag deposit recorded between Units A and B (Hiscock and Hughes 1984:12). Unlike Lawn Hill, the Gregory River corridor continued to provide a focus for settlement. While the area near Colless Creek Cave may have been occupied during this time, there is no archaeological evidence

in support and it is considered far more likely that the central area of the research region was abandoned during the peak of glacial aridity.

At GRE8 the flaked stone assemblage is constant in both weight and size for the entire LGM phase, contrasting with the pre-LGM where the average size of artefacts was significantly smaller. The assemblage is dominated by the locally obtained river chert and is highly reduced, as evidenced by the relative abundance of stone with little or no cortex, and flakes featuring overhang removal and thinner platforms.

At the same time that the flaking techniques tended towards conservation, there is a coincident change in faunal exploitation. The wide range of terrestrial faunas known from the earlier phase, were replaced by the mussel shell *Alathyria pertexta spp.* These shells were obtained from the local riverine patch of the Gregory River. The change in discard patterns implies an expansion of diet breadth to include a resource food of lower rank. In order to achieve a sizeable return, mussel harvesting necessitates significant investments in terms of handling and processing times. The expansion of hunter gatherer diet breadth to include this resource may have been triggered by increased patchiness of the local area and as a response to the increased foraging uncertainty associated with the LGM.

With climatic deterioration during the LGM, the more productive patches would have been reduced in number, size, and diversity. On the Gregory River, woodlands would have contracted and possibly disappeared from some areas. The less productive blacksoil plains grasslands and spinifex communities would have expanded to replace woodlands. The reconfiguration of habitats resulted in patchier food resources and increased foraging risk. The relative ranking of mussels was raised to a position where increased investments in time required to harvest the resource became necessary in order to maintain a presence

in this landscape. In phase B and C mussels became a feature of a specialized resource base.

Phase C: Climatic Amelioration during the Late Pleistocene (18,000- 10,000 Cal BP)

Phase C is marked by irregular improvements in climate. Average temperatures and rainfall gradually increased following glacial melting and flooding of the continental shelf. The Arafura Plain was quickly inundated around 10,000 Cal BP, changing the environment around the coast dramatically (Torgersen 1988). Within the research region the riverine fringing vegetation recolonised grassland areas, with resulting improvements in patch richness.

The first evidence for human occupation appears along the most substantial of the permanent watercourses. Along the Gregory River the GRE8 site continued to be visited and the accumulation at OLH midden began *c.* 15,000 Cal BP. Other middens, not yet identified, may have also been created at this time. In the central Lawn Hill area both Colless Creek and Louie Creek caves were occupied, and in the north of the study area the Bandangala 1 site at Musselbrook Creek was visited from about 13,000 years ago.

Occupation of the Gregory River

At GRE8 changes in the faunal and lithic records indicate transformations in subsistence strategies during phase C. In the lower spits which correlate to phase C, discard of mussel shell peaks before decreasing in the later phases. It is most likely that this indicates a focus on riverine resources and specialization on mussels during and immediately following the height of the LGM around 18,000 to 16,000 Cal BP. After this point discard of mussel shells decreases substantially and small mammal bone frequencies increase. There appears to be a shift in resource acquisition from riverine to a wider, more general focus. Smaller mammals increased in dietary importance, and effectively pushed the profitability of mussel

shell acquisition and consumption on site to levels that were below optimum level. Mussels may have still been exploited, but a change in patch use and resource acquisition perhaps occurred as climate ameliorated and substantially reduced their dietary importance.

The open midden site OLH, (and other dated middens), document the harvesting of mussel shells along the Gregory River *c.* 16,000 Cal BP. The OLH midden is almost one metre deep, and was deposited over a very short period of time, perhaps years or decades. This is not surprising as the enhanced rainfall led to expansion of the riverine vegetation and extensive tufa dam riverine micro-environments. The tufa dams created large slow moving pools associated with fast moving steams, while providing crossing places downstream. The dams provided access to large fish resources and to small mammals that watered at these locations while providing ideal habitats for *Alathyria pertexta spp.* colonies. The associated stream areas also provided easy access to the favoured chert river cobbles used for the manufacture of flaked stone artefacts.

The flaked stone assemblage at OLH indicates that the site was used for both the production and maintenance of stone artefacts. There is an abundance of cores at varying stages of reduction, whilst flakes are predominantly chert that feature little or no cortex. Formal chert artefacts include backed blades, notched retouched artefacts and a large number of tula-like flakes, indicating maintenance of wooden implements and perhaps composite tools. The OLH assemblage also contains a variety of stone raw materials including a significant amount of greywacke which is sourced *c.* 5 km distant. Flakes produced on greywacke are elongate and are generally indicative of blade production.

Similar trends to that shown in the OLH flaked stone assemblage are present at GRE8. During this post-glacial phase the average size and weight of flakes reduced to almost half of the previous phase, and indicates greater levels of stone reduction. Flakes also feature

smaller platforms and are more elongated. Chert continues to dominate the assemblage however raw material richness increases to include greywacke, quartzite and silcrete. Other trends in flaked stone reduction include higher frequency of flakes with dorsal cortex and greater occurrences of aberrant terminations. The increase in discard rates, coupled with a reduction in flake size, are most likely the result of more intense reduction of cores and retouched flakes during this time. Rather than increased reduction being a response to higher levels of risk, which one might expect, the trend at GRE8 appears to be the result of changes in subsistence strategies. In effect, a wetter climate and larger and finer grained profitable patches, led to changes in lithic reduction where artefacts were more reduced than previously, perhaps in the manufacture of hafted points to support hunting. The high discard rate of small flakes, elongate flakes and the high incidence of aberrant terminations all suggest point production. Direct evidence for point production is rare in any excavated site in the region, however the first unifacial point in the GRE8 assemblage occurs between 5,500 and 10,000 Cal BP during phase D (in Spit 4). Points have rarely been found in any site that is considered a residential base, and it is likely that they were discarded when broken or when reaching the end of their use - life.

Early point production at GRE8 is further supported in the occurrence of retouched flakes from approximately 14,000 Cal BP. These retouched flakes include amorphous retouched and notched flakes, and formal backed artefacts with evidence of hafting. The first example of grindstone technology also occurs in this phase at about 13,000 Cal BP.

The intensity of human occupation at GRE8 appears to increase substantially during phase C with a greatly increased rate of transverse flake breakage and increased sediment accumulation. During this period it is likely that shelters were used on a seasonal basis with significant changes in the demography of the river corridor after the LGM.

Occupation of Lawn Hill

At Colless Creek and Louie Creek Caves occupation sequences begin soon after the conclusion of the LGM. Trends in local resource exploitation correlate with a focus on riverine foods, indicating similar acquisition strategies to those seen along the Gregory River. During the first few thousand years of the post LGM phase at Colless Creek Cave, there was a strong reliance on riverine resources including mussels and fish. Colless Creek is a small tributary of Lawn Hill Creek and it is most likely that these resources came from about 700 m away at the junction of the two creeks. After *c.* 13,000 Cal BP there is a change to a broader resource base expressed as a replacement of mussels by higher ranked prey species. These changes are documented in both Colless Creek and Louie Creek caves. The degree of trampling indicated by artefact breakage at Colless and Louie Creek Caves also suggests that the intensity of occupation was greatest between 13,000 and 15,000 Cal BP.

Unlike the GRE8 assemblage, the discarded flaked stone at Lawn Hill is not as heavily reduced in the post LGM period, compared with succeeding phases. Although chert river cobble sources were favoured, reduction sequences here differed from GRE8. Flakes are larger than the later phases and much larger than those at GRE8 (*c.* 4 g). Knapping was forceful and controlled, as evidenced by less aberrant terminations, greater platform sizes and larger flakes (Hiscock 1988).

Occupation of Musselbrook Creek

The excavations at the Bandangala 1 site have shown that the northern river corridor of Musselbrook Creek was occupied from about 13,000 Cal BP. The deposit at Bandangala 1 extends beyond the excavated trench and may ultimately yield a longer cultural sequence.

However, based on the levels of flaked stone discard, it is concluded that the creek area were first occupied after the LGM when Musselbrook Creek would have had a more regular and stable water flow. During this post-glacial phase there are very few stone artefacts at Bandangala 1, and it appears that occupation of the Musselbrook Creek area was intermittent and by small mobile groups.

Phase D: The Early Holocene (10,000 – 5,500 Cal BP)

The early Holocene was characterised by a wetter and warmer climate than the preceding phases (Gagan *et al.* 1994; Kershaw 1983, 1995; Kershaw and Nix 1989; McGlone *et al.* 1992; Nix and Kalma 1972). These climatic conditions facilitated an environmental recovery from the glacial contraction of vegetation and faunal habitats along the rivers of Riversleigh/Lawn Hill. Fringing riparian corridors and woodlands expanded with a corresponding increase in patch richness and grain.

Phase D is represented in the regional archaeological record by the rockshelter sites of GRE8 at the Gregory River, Colless Creek Cave and Louie Creek Cave at Lawn Hill Creek, and Bandangala 1 at Musselbrook Creek. It is also likely that numerous undated artefact scatters, consisting of very weathered artefacts, also date from this period (*cf.* Hiscock 1988).

During the early Holocene, use of all four rockshelter sites decreased as seen in a lower incidence of flaked stone artefacts and faunal remains. At GRE8 and Colless Creek Cave, the occurrence of mussel shells also decreases, corresponding with increases in discard of small and medium to large mammal remains. At both sites the general overall reduction in faunal material perhaps indicates less food was prepared and consumed in the caves.

At GRE8 the flaked stone assemblage contains fewer artefacts. There is a continuation of the trend to smaller artefacts and there is a higher incidence of small platforms and overhang removal on flakes. The retouched flake assemblage is smaller in number than the previous phase, however it features unifacial points and the first occurrence of a tula adze (spit 4). At Lawn Hill, Colless Creek and Louie Creek Caves show a general trend to a physically smaller assemblages with a further reduction in the size of flakes and a correlate increase in focal platforms combined with a low incidence of retouch. There is also a shift from the use of local chert river cobbles to quarried chert, which was available nearby. Non-local stone accounts for up to 40% of the assemblage at these sites during this phase. Finally at the Bandangala 1 site, the flaked stone assemblage features very high rates of discard and high raw material richness.

Flaked stone assemblages from all sites indicate less intensive use of the immediate areas and greater use of more distant stone sources and patches. There is a general decrease in the abundance of retouched artefacts in all sites at this time, which can be interpreted as a function of limited curation or less reduction at specific cave locations. It is most likely that the trend relates to specific site and patch use rather than a broader trend in technological strategies. Flake size, platform sizes and the occurrence of overhang removal all indicate early to late stages of manufacturing on site. It is likely that the production of retouched implements occurred elsewhere. Knapping locations were probably near outcrops and large water bodies as seen at the OLH midden (*cf.* Hiscock 1988:88).

Phase E: El Nino Mid Holocene (5,500 – 2,000 Cal BP)

The mid Holocene was characterized by a general trend to aridity in northern Australia. During this time the archaeological evidence for human occupation in this region is limited

to GRE8, Wild Dog Dreaming (at Lawn Hill), and Bandangala 1 (Musselbrook Creek). At GRE8, stone artefact reduction becomes more conservative with features similar to the phase B (the LGM) assemblage. These include a reduction in raw material richness, general reductions in flake size and a trend towards elongation. Flakes are generally without cortex, feature the greatest percentage of overhang removal and the smallest platforms.

At Lawn Hill, Colless Creek and Louie Creek caves appear to have been abandoned during this phase. However, open middens within the gorge system such as Wild Dog Dreaming (WDD) support the notion of a second arid phase driving a focus on riverine resources and reduction in foraging range. At WDD occupation begins *c.* 2,700 Cal BP. If the associated flaked stone scatters are of a similar age then foragers were firmly focused on local resources including artefact manufacture similar to at Colless Creek Cave during the post LGM phase at about 16,000 Cal BP.

At GRE8 the 'arid phase' is coincident with the highest occurrence of transverse breakage of stone flakes, indicating an increase in occupation frequency from phase D. There is also a further increase in small mammal remains. At Bandangala 1 sediment accumulation is reduced compared to other phases, though the rates of transverse flake breakage are high, indicating more intensive occupation. There is a similar trend towards more elongate flakes as seen at GRE8. At both sites there is also a notable rise in the frequency of backing retouch.

The flaked stone assemblages at both sites indicate conservative use of raw materials and a focus on local resources within gorge riverine patches. These trends in flaked stone manufacture support the risk-sensitive models such as that proposed by Hiscock and Attenbrow (2002). They suggest that during the El Nino period of increased aridity

foragers responded to increased foraging uncertainty with a corresponding proliferation of technologies that reduced foraging uncertainty. In particular, the proliferation of backing retouch on small flakes for use as barbs on composite projectile weapons is suggested as one means of increasing tool utility and effectiveness.

Phase F: The recent past (2,000 Cal BP – present)

This most recent occupation phase features a semi-arid monsoon climate, as seen today. Patches and habitats remained relatively constant. Four excavated sites have occupation sequences covering this most recent period. In addition, it is likely that many of the extensive flaked stone scatters and deflated surface shell scatters also were discarded during the last 2,000 years. It is interesting to note that none of the other sites investigated during this study, that are close to permanent water, were occupied during this phase. The most recently occupied sites consist of a variety of shelters and caves at varying distances to permanent water and within marginal patches.

At Riversleigh, LH23, GRE13 and Gamanyi have all been dated to within the last 1,000 years. Occupation of the LH23 rockshelter occurred during the last 700 years, and may predate this time. The site is a small shelter on an ephemeral creekline. The relative abundance of small lithic debris and backed artefacts indicates that the Verdon Creek locale was a productive patch during periods of creek flow as groups traveled between the larger river courses following the amelioration of El Nino aridity. Similarly, the GRE13 site, which is located at the intersection of the limestone plateau and grasslands, and not in close proximity to water, was also occupied intermittently over the last 600 years. The site features a chert assemblage in late stages of reduction and a meager faunal assemblage which includes shell, and a range of large and medium mammals. The paucity of cranial

material and the dominance of lower limbs and ribs indicates that animals were transported to this location following capture. Finally at the large cave complex of Gamanyi, there is evidence of Aboriginal occupation within and outside the cave, dating from at least 1,000 Cal BP.

A second new area with occupation during phase E is Elizabeth Creek. At AL:B37 a few flaked stone artefacts and a dense layer of charcoal are dated to the very recent past. If the production of art at this site is coincident with the age of the deposit (*i.e.* 147 Cal BP), it provides a recent minimum age for the art style described as freehand figurative. The art at AL:B37 includes yellow arched motifs that are also present at 15 other known art sites, including Bandangala 1 and Wild Dog Dreaming. This regional art style may signify a continuity of the present linguistic group over the entire northern half of the research region. The absence of similar motifs in the south is considered to be primarily the function of a different geology that does not facilitate the production of art. At Bandangala 1 there is a good likelihood that occupation of the site also continued to this recent period. Unfortunately evidence for recent occupation has been scoured away by recent flooding.

Undated surface assemblages occur in all environmental zones across the research region, although they are rare and spatially limited on the limestone plateau and grassland plains. As with Hiscock's 1988 surveys, the current research found that areas near to permanent water and quarry sites more frequently contained sites than those farther away. Areas closest to quarries (including the chert river cobbles located along river courses), contained the highest frequency of flaked stone artefacts. Hiscock reported that over 80% of all sites in the Lawn Hill area were situated within 3 km of stone sources, or within 3 km of permanent water, and 100% of sites were within 3 km of either water or a quarry (Hiscock 1988:81-88).

Areas near permanent water were used as central places within a foraging range. It is expected that residential locations within the most productive woodland and riverine patches were always extensively utilised with low residential mobility outside of these areas. Within these patches residential mobility would have fluctuated, based on the particular location (*i.e.* areas along the side of large waterholes were more productive than shallow stream areas and would have lower levels of mobility).

Within the woodland patches on the river corridors there are differential rates of lithic discard. Areas on levee banks, *e.g.* Wild Dog Dreaming, Danjadanji, and along the Gregory River, feature higher frequencies of flaked stone discard and this appears to be the result of a combination of taphonomy and hunter-gatherer preference for well treed flat areas, which also have finer grained sediments (*cf.* Hiscock 1988). Undated surface assemblages are also related to the availability of seasonal water and shelter.

The most recent phase of Aboriginal occupation within the research region encompassed all major river systems. During this period site location was strongly correlated with distance to permanent water and stone sources. It is also most likely that during this recent phase most of the rock art within the study area was created.

8.2 Archaeological models revisited

8.2.1 Antiquity of Occupation and Settlement of Northern Australia

The timing of entry by people into Australia continues to be a key question for Australian prehistory. There are two competing arguments: a long > 60,000 year occupation or a short *c.* 45,000 year chronology (Allen and O'Connell 2004; Gillespie 2002; Roberts *et al.* 1994; Thorne *et al.* 1999). The occupation of GRE8 and the Gregory River corridor commenced sometime before 37,000 Cal BP. Age-depth curves indicate that the lowest

artefacts in GRE8 are possibly 45,000 Cal BP. However, caution must be observed as these artefacts comprise a small assemblage and co-occur with a limestone rubble matrix, and may derive from slightly younger sediments. The occupation of GRE8 from about 40,000 Cal BP provides the first conclusive evidence for early occupation in this part of Australia, and compares in age with Ngarrabullgan to the east (David and Dagg 1997; David *et al.* 2007). Importantly the archaeology of the Gregory River corridor provides insights into the possible routes by which people entered Australia and perhaps the arid zone.

The timing of occupation at GRE8 and Ngarrabullgan offer compelling evidence that colonisation routes are consistent with Birdsell's argument for a northern route into Australia through New Guinea (*cf.* Birdsell 1977). Colonisation pathways for the east of Australia would have followed two possible pathways: around the west of Lake Carpentaria or down the east coast. Arrival via the edge of Lake Carpentaria at about 45,000 Cal BP would have followed major rivers and associated fine grain patches. Upon reaching the southern extent of Lake Carpentaria the main drainage systems provided access inland. The most significant of these rivers are in the southern Gulf and include the Nicholson, Gregory, and Leichhardt. It is along these three rivers and their tributaries within gorges that the archaeological signature is greatest.

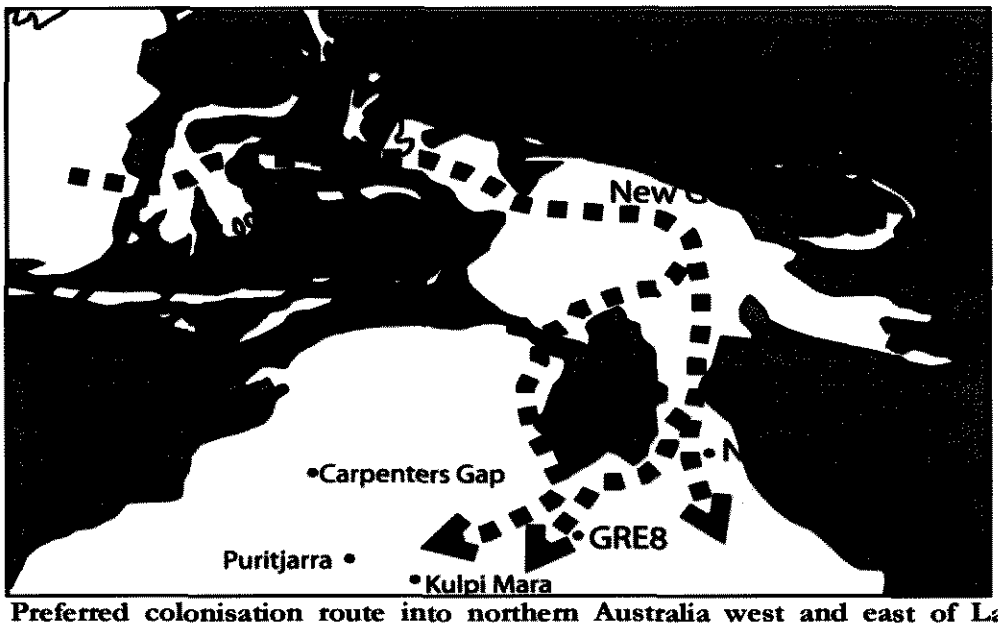

Figure 8.2: Preferred colonisation route into northern Australia west and east of Lake/Gulf of Carpentaria.

The settlement of the arid interior is another important issue in Australian prehistory. Excavation at Puritjarra has shown that people were present in central Australia from approximately 40,000 Cal BP (Smith 1988, 1993). Colonisation may have been facilitated by 'corridors' during the late Pleistocene (Veth 1993), though currently there is no directionality in the archaeological evidence to support any particular model for arid zone settlement (Hiscock and Wallis 2005). However, the early occupation of the Gregory River provides support for Veth's corridor settlement model. People living in the Gregory River environs were only separated by *c.* 30 km of poorer less watered country, from the head of the nearby Georgina River near present day Camooweal. The Georgina River is a part of the Lake Eyre Basin and would have provided direct a conduit to inland and southern Australia, including the Puritjarra/Kulpi Mara region.

8.2.2 Occupation during the Last Glacial Maximum

The last 20 years in Australian archaeology has been dominated by arguments that most of inland and Northern Australia was abandoned during the height of the Last Glacial Maximum (Hiscock 1988; Smith 1988, 1989, 2006; Veth 1989, 1993). General consensus has been that the interior of the continent became too arid to sustain a human presence and that people retreated to other more temperate areas until conditions improved (but see Smith 1988, 1996, 2006). The bio-geographic model developed by Veth posits that during the Last Glacial Maximum humans retreated to what have been variously referred to as 'refuges' or 'oases' (see Veth 1993; Hiscock 1988).

The search for archaeological sites that provide evidence of 'refuge' occupation has targeted likely geographic zones (see Marwick 2002; Veitch *et al.* 2005; O'Connor and Veth 2005). However, the evidence for any archaeological LGM refuges is still sparse and requires more data. Three regions of northern Australia have been claimed to provide evidence for refuge occupation; the Hamersley Plateau, the Carpenter's Gap area of the Kimberley's, and Lawn Hill. Evidence for Pleistocene occupation of the Hamersley Plateau is at present inconclusive. Until detailed chronologies, lithic assemblages and new excavations are reported, a refuge region cannot be supported. At Carpenter's Gap, occupation during the LGM has only recently been claimed (O'Connor and Veth 2005). This is reliant on a combination of site data, including a mix of site chronologies and lithic assemblages which at present is inconclusive. Finally, refuge occupation has previously been argued for the Lawn Hill area (Hiscock 1988). Lawn Hill was occupied before and after the height of the LGM, but there is more evidence for abandonment of this area during the LGM than for it being a refuge. Hiscock has only ever claimed that the Colless Creek cave provides evidence of occupation post- LGM (Hiscock 1988).

Evidence for human occupation within the study area during the LGM is restricted to GRE8. This site is small, and a lengthy temporal period is represented within approximately 20 cm of deposit. Consequently the nature of occupation at this site, and the Gregory River 'refuge' might be interpreted in three ways (after Hiscock 1988:257): *(i)* the area was a true refuge and that a small population occupied the Gregory River gorge consistently during the entire LGM; *(ii)* people visited the gorge on a regular basis but short term basis and that their residential bases were elsewhere (most likely to the east near to Lake Carpentaria); or *(iii)* visitation to the site was very infrequent over the LGM and that people were located much further away.

At GRE8 occupation persisted during the LGM, as foraging territories contracted, and strategies were implemented to minimize foraging uncertainty, including specializing in a resource that expanded diet breadth. It is likely that GRE8 was one of an unknown number of occupied locations at Riversleigh during the LGM. When considering the concept of a refuge it is necessary to view the entire Gregory River region as a refuge, rather than just the gorge and GRE8 (contra Hiscock 1988). However, no other archaeological sites known from this region to date to this period. The absence of stone raw material that was sourced any distance from the Gregory River gorge does not suggest mobility along the river from GRE8.

Consequently, the Gregory River data is interpreted as providing compelling evidence for persistent human occupation of the region during the LGM (30,000 and 18,000 BP) rather than short term visitation from somewhere else. Resource procurement strategies at GRE8 feature a subsistence strategy that is purely focused 'inwards' on local riverine resources and immediately local stone raw materials. There is no evidence of any stone raw material that might have derived from outside the refuge area during the LGM, in contrast to earlier occupation that focused on both the river valley and neighboring plains

with exploitation of a broader resource base. The increased aridity of the LGM resulted in a contraction of range to the 'refuge', *i.e.* the gorge sections of the Gregory River, with limited foraging ranges, and ultimately specialization in local lower ranked resources.

This refuge occupation persisted until *c.* 16,000 Cal BP, whereupon foragers became outwardly focused once again. With climatic amelioration foraging range expanded to include the eastern plains, new technologies were developed, a wider range of stone raw materials were exploited and overall residential mobility increased with re-occupation of Lawn Hill. It remains unresolved as to whether refuge occupation persisted, and if these changes occurred due to environmental changes or if new populations entered the region the way that the original colonists did.

Settlement re-configurations in the study area were definitely made possible by climatic amelioration post-LGM. Soon after Lawn Hill was re-settled, Musselbrook Creek was also visited. However, the nature of occupation in this northern part of the study region was more short term, variable and probably more seasonal than the occupation of the southern research area. Due to the ephemeral nature of Musselbrook and Elizabeth Creeks, the northern study area has never been as productive and resource rich as the south. While Riversleigh and Lawn Hill feature stable water flow and large freestanding pools created by tufa dams, the northern rivers are less stable. During more arid conditions, Musselbrook and Elizabeth Creeks are reduced to a series of billabongs with far lesser patch productivity than in the south. During periods of aridity, visitation of the northern area would likely have been short-term from residential bases south at Lawn Hill.

8.3 Evolutionary Models and Archaeology

The evolutionary approach used here provides a strong theoretical background upon which to model expectations of human behaviour that are readily observable in the archaeological record. Use of the various models of HBE allows archaeology to move beyond the use of ethnographic analogy (see Barton 2001:354). HBE also allows us to observe complexities in behaviour that might not be apparent in the archaeological record (Bird and O'Connell 2006). It provides an interpretive framework that is based on functional explanations of behaviour, rather than historical contingencies. As human behaviour is driven by evolutionary mechanisms, HBE provides the only real theoretical way of explaining behaviour, including that of the past.

The HBE model developed for this study has been subject to extensive testing through the excavation of archaeological sites in different patches, locales and regions of the study area. However, as with any theoretical approach there are strengths and weakness in the way in which HBE has been applied to the research area.

There are three primary strengths to the approach taken here: *(i)* the HBE model is simple and testable; *(ii)* the analysis of flaked stone artefacts readily lend themselves to HBE based hypothesis testing; and *(iii)* faunal analysis is also readily applicable to HBE models. The patch choice and diet breadth models were developed within a landscape that has been well mapped, where the location of critical resources is known and are also relatively constant. With these constants relatively known for the region, this has allowed for changes in site use, technology and faunal exploitation to be identified, and related to functional explanations of behaviour.

The weaknesses of the HBE approach relate to the nature of the palaeo-ecological and archaeological records, both for the region and more generally. The model is necessarily

based at this time on very coarse environmental data. Reconstructions of local environment are reliant on proxies for distant areas. It is hoped that future palaeo-environmental research might target the study area and provide better scaled data. Detailed observations of foraging behaviour are also limited here by the coarseness of the archaeological record and problems of equifinality (see Cosgrove 2000:187-88). These problems are especially pertinent for northern Australia where deposits feature many thousands of years of occupation in just a few centimetres depth making it very challenging to undertake detailed appraisal of the HBE models more than generally. In addition, the practical challenges of the temporal and geographic spread of the suite of sites analysed has presented a further issue; for example OLH is a rapidly accumulating deposit spanning a few hundred years in c. 1m depth, whilst GRE8 spans 40,000 years and is *c.* 55cm in depth.

The second limitation of the HBE model approach to the research project has been in the relationship between the nature and extent of patches and habitats and the foraging model itself. The model focuses on a detailed level of local habitats, and the actual archaeological sampling was designed accordingly. However, rather than detailing specific relationships between sites and local patches in all instances, the results of this research have highlighted larger scale trends in regional land use (*e.g.* between the nature of patches in the north versus the south of the study area). It could be argued that it is only the significant changes in subsistence manifested in shifts in stone technology and/or faunal exploitation that become evident in the archaeological record. These changes correlate to either significant or prolonged periods of climatic change, or to the local landscape scale of patches. Further testing of the propositions of the model is required. Excavations at other substantive rivers to the north, specifically along the Nicholson River, might address these issues.

8.3.1 Optimal foraging theory

The archaeological records from Riversleigh and Lawn Hill provide compelling evidence for humans to have always aimed at achieving an optimum in diet by resource procurement, through strategies aimed to minimize foraging uncertainty. The ways it was accomplished here have included flexible settlement patterns, resource procurement and adaptive changes in lithic technology. At times these changes have been significant, for example during and immediately after the Last Glacial Maximum when a resource procurement strategy targeted a low ranking resource prior to developments in stone technology (coinciding with environmental changes) facilitated changes in diet breadth.

The HBE derived model predicts a mix of residential bases, short term camps and limited activity areas for different patch types in the research region. Residential bases were predicted to be in close proximity to permanent water, shelter and stone resources, and as such would to focus on the gorge areas of the major rivers in the region. All gorges had the potential to show signs of occupation from or before the LGM. However, as the archaeological record shows, some creeks were not occupied until post-LGM climatic amelioration, and others were abandoned during the LGM. The Gregory River provided a focus for settlement since human arrival. The low resolution of occupation sequences allows broad temporal trends to be evaluated but precludes assessment of prey seasonality, patch and travel thresholds relating to resource procurement. Observations based on mammal remains were explored to further understandings of occupation patterns but were unfortunately limited.

Short term camps were predicted to occur along seasonal and ephemeral watercourses in areas near stone sources, and this prediction is supported by the data. Short term camps were created during periods of high residential mobility and featured evidence of tool curation plus debitage and was related to maintenance of artefacts rather than their

production. At the Verdon Creek shelter, there is clear evidence for stone assemblages consistent with this expectation, though here there is also evidence of expedient reduction sequences such as backed artefact production. Short term camps in more marginal environments might have come unexpectedly very late in the regional archaeological record. However, interpretations of the recent past are benefit from better archaeological resolution than older phases. It is likely that short term camps occurred throughout the research region along seasonal watercourses during older periods of climatic stability.

8.3.2 Technological provisioning and stone artefact technology

The technological organization of flaked stone artefact manufacture can provide insights into the ways in which foragers structured activities and the strategies they used for resource procurement. Flaked stone artefact studies have shown that various forager performance characteristics including time budgeting, mobility constraints, design theory and utility can be examined archaeologically (Clarkson 2004:66). The nature of tool provisioning within the study area and whether it was a specific task or fitted in with other tasks, shows that time budgeting was not a strong limitation on foragers. Changes in mobility constraints are evident in the regional record and are directly related to regional climatic changes and localised environmental adjustments. For example during periods that featured greater logistical mobility, raw material richness increases correspondingly.

Investment in tool design and manufacture are usually expected during periods of increased diet breadth at times of increased risk that correlate to environmental and resource stress (see O'Connell and Hawkes 1984). As such, greater tool diversity would be expected during periods of resource or environmental stress as people modify procurement strategies to solve technological problems and enhance their ease of prey

capture. At Riversleigh and Lawn Hill, climatic flux and its environmental consequences forced an increase in diet breadth, which was manifested as resource specialization (particularly during the glacial period). Investments in tool design appear only after this period as climate and resource availability improved.

Stone artefact technological strategies are aimed at either providing increases in utility or reducing risk, and involve the development of more elaborate technologies, use of different raw materials and variations in procurement strategies. The flaked stone assemblages recovered from excavations at Riversleigh and Lawn Hill are consistent with reduction sequences producing expedient tools. Although only a few retouched artefacts were recovered and were predominantly derived from those sites classified as residential bases, the timing of their introduction is of interest. Tulas and backed artefacts were recorded in phase C (18,000 Cal BP-10,000 Cal BP) from two sites. This is consistent with climatic amelioration and a period of improved foraging outcomes (see also Hotchin 1982; Hiscock and Attenbrow 1998). Introduction of these technologies therefore must be associated with attempts to provide utility gain as foraging activities resulting in a reconfiguration of targeted resources, with a focus on higher ranked animals. The introduction of greywacke after 14,000 Cal BP and associated changes in core reduction which produced long blade flakes, was also a strategy that facilitated a change in diet breadth. The shift in raw material provided higher utility in the form of formalized new artefacts (i.e. points), and may have reduced risk through composite weapon development and hafting.

Changes in technology are related to design changes aimed at utility increases. At Riversleigh and Lawn Hill the main design changes involved standardization by hafting, portability, versatility and flexibility. The extension of artefact use-life does not appear to have been a focus of knapping behaviour, but a function of abundant raw material availability. Attempts to standardize tool kits did occur, but mainly during the late

Pleistocene and mid Holocene. These periods involved the production of backed artefacts (flexible designs), points, and tulas and often feature evidence of hafting. During periods of greater logistical mobility there are a greater number of small tools indicating both portability and versatility.

Conclusions

This thesis has presented the results of excavations at eleven sites in northwest Queensland and detailed consideration of two investigated by Peter Hiscock (1988). It found that humans have occupied the southern and central parts of the research region from at least 40,000 BP. Re-configurations in human behaviour were found to be consistently related to changes in local environmental conditions brought about by climate change. Shifts in resource exploitation from dispersed to locally available resources, changes in reduction strategies and the subsequent composition of flaked stone assemblages as well as expansion and contraction of foraging ranges, can all be correlated to fluctuations in environmental conditions.

The Riversleigh data show that humans had colonised the inland region to the south of the Gulf of Carpentaria by 40,000 BP. This evidence supports a northern colonisation route of highly mobile groups who targeted high ranked resources and followed the shores of the Gulf, before progressing inland along the major permanent rivers, such as the Gregory River. People remained in the Gregory River valley and surrounds during the most extreme climatic conditions. During the LGM a small population persisted in the refuge provided by the permanent rivers in the local Riversleigh area; a refuge location, targeting low ranked mussels. These results are consistent with Veth's (1993) bio-geographic model of arid settlement.

Using an HBE approach this project has provided new data for northern Australia that is important for our understanding of the process of human settlement of the continent, the colonisation routes and the subsequent timing and pattern of occupation of the arid zone. In these ways the archaeological data presented here has provided important new insights into the prehistory of continental Australia.

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