Dangerous Harvest Revisited: Taphonomy, Methodology and Intensification in the Central Queensland Highlands, Australia

General view of the sandstone escarpment of the Central Queensland Highlands
Courtesy National Library of Australia, Frank Hurley Collection

Brit Asmussen

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To the best of my knowledge the research presented in this thesis is my own except in cases where I acknowledge the work of other researchers. This thesis has not been submitted in any form for any other degree at this or any other University.

[Signature]

Brit Asmussen
Abstract

This thesis argues for, and demonstrates the potential of, a positively focussed, ecologically grounded, taphonomic analysis of archaeological sites in the Australian context. It provides a detailed taphonomic analysis of three archaeological sites in the Central Queensland Highlands, Australia. A broad taphonomic analysis combining ecological, geomorphological and taphonomic methods was applied to multiple lines of archaeological evidence. In doing so it provides a substantial reinterpretation of the archaeological records and taphonomic histories of these sites, which has significant implications for original interpretations of mid Holocene change in the region, and Australia more generally, and raises important methodological and interpretive issues for Australian archaeology in general.
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Chapter 1: Introduction and Problem Definition

...the ultimate goals of Australian archaeology have shifted little in the last 20 years (Fullagar 1994:69)

In Australian archaeology...we perceive a tendency for science not to progress, but rather to go round in circles (Bowdler and O'Connor 1991:53)

...modern taphonomic analysis is seldom straightforward (Lyman 1994:7)

Up until comparatively recently, the working assumption in the analysis of archaeological sites was that the components of the archaeological record were the remains of anthropogenic activity and the cultural uses of artefacts (Bonnichsen 1989a:517; 1989b; Hassan 1987; Schiffer 1972, 1974, 1976, 1987, 1988, 1995, 1996). Thus the analysis of variability in the archaeological record was considered to directly reflect cultural differences and or cultural affiliations (Hassan 1987:1-3; for similar arguments see Bonnichsen 1989b:1, Erlandson and Rockwell 1987:51, Lyman 1994: Chapters 1-2; Petraglia 1987:25; Tani 1995:231; Zutter 1999:833). A major theoretical and methodological shift occurred in world archaeology in the 1970s, particularly in America, as a result of formation process research and the application of taphonomic perspectives and analytic techniques to the interpretation of archaeological sites. Taphonomy, which includes both the study of the transition of organics (and inorganics) from the biosphere to the lithosphere (Efremov 1940), and the study of how preservation processes have effected information in the archaeological record (Behrensmeyer and Kidwell 1985), has been of major importance to the discipline as a whole.

The recognition that archaeological data are the end result of a series of taphonomic processes fundamentally changed how assemblages were perceived and interpreted (Behrensmeyer 1993:343; Bonnichsen 1989b:1; Hassan 1987:2; Lyman 1994:8; Schiffer 1972, 1974, 1976, 1978, 1987, 1988, 1995, 1996; Schiffer and Rathjie 1982; Schiffer and Skibo 1987; Stein 1983, 1987, 1992, 1993; Tani 1995; Wildesen 1982). Archaeologists recognised that simple analyses of sites and their contents; often based on the analysis of variance in the quantities, types and distributions of archaeological remains; were unlikely to reflect a straightforward record of human activities (Hassan 1978, 1987:2). They realised that a significant portion of the archaeological record was formed by an “intertwined matrix” of both cultural and natural transformation processes rather than by human behaviours alone.
Clearly, taphonomic processes needed to be understood before the contents of archaeological sites could be used to address archaeological questions of human behaviour.

In order to unravel the intertwined histories of the actors in archaeological sites, archaeologists realised that they needed to understand the range of natural and cultural site formation processes on the archaeological record (Behrensmeyer 1993:343; Butler and Schroder 1998:957; Colley 1990:50; Denys 2002:470; Haglund 1991; Hassan 1987:5; Lennstrom and Hastorf 1992:205; Lyman 1994; Schick 1987; Schick et al. 1989; Schiffer 1974; Shackley 1972, 1974, 1978; Martin 1999; Tappen 1994:667). To this end, archaeologists set about building up a methodological and analytical toolkit using a range of methods including experimentation and actualistic studies. Answers to the fundamental taphonomic question: “what agents or processes (and their combinations) have acted to form and modify the site and its assemblage” (Lyman 1994) are now becoming available.

Although most frequently dealing with the taphonomy of vertebrate remains, studies are also beginning to include invertebrate faunal remains, botanical remains, and the “enduring and inedible” lithic materials (Shipman 2002; see also Hiscock 1990a, 1990b; Mountain 1999:vii). As the role of taphonomic analyses in the discipline of archaeology develops, so do comprehensive reviews on the subject (for examples see Allison and Briggs 1991; Behrensmeyer 1984; Behrensmeyer and Kidwell 1985; Cadee 1990; Gifford 1981; Hassan 1987; Hill 1989a, 1989b; Lyman 1994; Martin 1999; O’Conner 1996; Shipman 1981; Solomon 1985; Stern 1980).

**Constraints on Taphonomic Approaches in Australia**

Taphonomy has had less impact in Australia than overseas. In Australia, although researchers now often acknowledge the importance of taphonomy, few researchers are actively engaged in taphonomic analyses or experimental research.

**Disciplinary Constraints**

Some archaeologists have acknowledged that current arguments regarding past human behaviours are potentially inaccurate because of a lack of taphonomic understanding in the analyses of Australian sites and regions (Davidson 1988, 1990, 2000; Frankel 1988, 1991a, 1991b, 1993; Hiscock and Clarkson 2000; Mountain 1990, 1999:v; Solomon 1985; Stern 2
To date, only two taphonomy conferences have been held in Australia, in 1987 and 1994, the proceedings of both conferences were published 1990 and 1999 respectively. These conferences give Australian archaeologists a focus for the practice of taphonomic principles within Australian site conditions and practical examples (Mountain 1999:v-vi). However, very little of this work has been done.

These problems are also exacerbated by a general lack of interest in these issues in the wider Australian archaeological discipline. Taphonomic concerns are not usually integrated into mainstream research agendas. Even though some taphonomically based reanalyses have resulted in significantly different reinterpretations of identical assemblages and sites (e.g., Walshe 2000 cf. Gould et al. 2002, see also Gould 1996), taphonomic analyses are generally treated as an optional specialist field rather than the precondition for sound archaeological interpretation.

**Practical Constraints**

As is the case overseas, taphonomic research in Australia tends to be conducted in local, small-scale research programmes aimed at the resolution of specific problems in sites. The effects of most taphonomic agents are often context specific. As a result, an understanding of taphonomic agents, processes and effects need to be developed in the Australian situation. However, there have been relatively few studies in Australia of how sites and their contents are the product of many taphonomic processes and effects occurring before, during and after human occupation (Clarke 1999; Dortch 1984; Dortch and Merrilees 1971, 1973; Field 1999; Hope 1978; Littleton 1999; Marshall 1989; Mitchell 1988; Robins 1999; Walshe 1994a, 1994b, 1999, 2000:74). Important contributions to the understanding of taphonomic processes have been performed as part of research dissertations but they are rarely published, and difficult to find except by word of mouth. There is relatively little taphonomic data concerning specific Australian taphonomic processes, agents and effects.

Most of the taphonomic research that has been conducted has focussed on fauna of mid-late Holocene antiquity. However, important taphonomic and archaeologically oriented studies have been conducted on the modification of faunal remains by the dingo (*C. lupus dingo*) (David 1984; Hutchet 1990; Solomon 1985; Solomon and David 1990), and the human fracture of long bone shafts of Macropods has been simulated using glass tubes (Archer et al. 1980). Actualistic studies of dingo reduction of Macropod carcasses have also been conducted (Solomon 1985; see also Solomon and David 1990). The taphonomic
modifications of owls have also been studied (Baird 1982; Dodson and Wexlar 1979; Geering 1990; Walshe 1994a; Worthy and Holdaway 1994).

In Australia, most taphonomic work concerning shellfish has focussed on taphonomic modifications in shell middens. However there has been little study of the effects of humans in the fragmentation of shell during the extraction of the edible meat (Meehan et al. 1985; Mowat 1994, 1995). The main taphonomic research has concerned the effects of animals on specimen size and mound integrity (Bailey 1991, 1993; Burns 1994; Dwyer et al. 1985; Hallam 1967; Jones and Allen 1978; Meehan et al. 1985; Stone 1989), and the effects of thermal modification and sieving stress on various species of shellfish (Robins and Stock 1990; Spenneman and Colley 1989). One study analysed the relationship between differential survivorship and fragmentation and different taphonomic processes on different shellfish species within midden assemblages (Mowat 1994). Theoretical (if not practical) tests of the effects of chemical processes on shells in sites have also been conducted (Bourke 2000; Hughes and Lampert 1977; Mowat 1994, 1995; Sullivan 1984).

There has been some acknowledgement of the important role of taphonomic processes in the interpretation of floral specimens in assemblages (Atchison et al. 2004). However there has been relatively little work on the taphonomy of plant remains in Australia. There are only a few specialist researchers (Beck 1985, 1990; Beck et al. 1988; Clarke 1988, 1999; Murphy 1992). To date, the only actualistic experimentation has concerned the fracture of Cycas sp., Macrozamia sp. and Lepidozamia sp. (Beck et al. 1988; Beck 1989; see also Chapter 7), and interpretations of decay curves for plant preservation in rockshelter sites (Clarke 1999).

In Australia, taphonomic work has been conducted on lithic remains, as it is relatively easy to adapt methods and interpretations from overseas contexts. These include the effects of vertical movement of lithic artefacts (Stern 1980; Stockton 1977), in situ weathering by (Hiscock 1990a), the effects of thermal modifications (Flenniken and White 1983; Mercieca 1999), and tests of stratigraphic integrity using artefact refitting (Richardson 1992).

Impact of the Wider Research Agenda

These problems with taphonomy in Australia can be traced, in part, to the impact of the wider research agenda of the last few decades. Australian archaeology is a relatively young discipline. Once basic questions about the antiquity of occupation and the distribution of archaeological materials were addressed, archaeologists turned their attention to creating
explanatory models of regional and continent-wide prehistoric change. These models seek to explain the temporal and spatial distribution of archaeological materials and the prehistory of the continent (Beaton 1977, 1982; Birdsell 1967; Bowdler 1977; Jones 1973; Lourandos 1980a, 1980b, 1983a, 1983b, 1985a, 1985b, 1994, 1997; McBryde 1974; McCarthy 1964; Mulvaney 1959, 1960, 1975, 1987; Schrire 1982; Smith 1988, 1989; Tindale 1940; Tindale and Birdsell 1941; Veth 1989; White 1967). They assume that widespread patterns of site occupation and changes in quantities of archaeological material through time are best understood as reflecting large-scale prehistoric change. By amalgamating simple data from many individual sites, broad patterns of prehistoric change can be revealed.

As a result, many of the fundamental methodological, taphonomic and interpretive issues raised in overseas contexts have been side-stepped, or given less attention. Unfortunately, the assumptions behind this explanatory approach are not valid. They underestimate the power of purely taphonomic processes to create the patterns in the archaeological record currently interpreted as long-term prehistoric change. The only way of developing and testing these kinds of high-level models is to do the basic taphonomic research and create the kind of detailed local analyses needed to extract reliable information about human activity from the complex, often heavily overprinted assemblages common in Australia.

The Intensification Model

Several researchers in the late 1970s separately argued for what they each saw to be significant changes occurring in some analysed sites of mid-late Holocene antiquity (Beaton 1977; Lourandos 1983a, 1983b, 1985). Lourandos was the major proponent of the argument for mid Holocene, continent-wide changes, or "intensification", which he saw as developing as a result of social processes. Lourandos adapted models of cultural change in Europe (Soffer 1987, 1989; Zvelebil 1986), and drew on studies of the origins of sedentism and domestication (Golson 1977), which he applied to the Australian hunter-gatherer context. The strategy that was used to identify this large scale process of social intensification was to define a wide set of archaeologically visible correlates; simple patterns in the archaeological record that would be expected if the model were true (Lourandos 1983a, 1983b, 1985a, 1985b). These included:

- Increase in site numbers
- More intensive use of sites (reflected in increased discard rates)
- Use of new environments, particular marginal environments (rainforests, gorges)
- Broadening of resource base (new resources, particularly high effort resources)
- Introduction of new economic technologies (seed grinding, microliths, hafting)
In each case, fairly simple patterns in the number of sites, the quantities of archaeological material and changes in the lithic and faunal assemblages within sites were seen as reasonably adequate indicators and tests of the model. Initial analyses in the early 1980s by several researchers, based on collating results from many sites (e.g., Lourandos 1983a, 1983b, 1985a, 1985b, 1997; see also Barker 1991:103, 1996:32-33; Blackwell 1982:51; David 1994; Morwood 1979, 1980, 1981, 1984:347, 1995:750; Ross 1985; Walters 1989:219), indicated the presence of many of the broad archaeological signatures predicted by the model.

What followed was an ongoing debate about the origins, scope and nature of mid-to-late Holocene change, and with it, methodological arguments about how such topics could be best addressed and tested. Alternative explanations were offered for the causes of identified changes, including population increase (Beaton 1983, 1985, 1995; Frankel 1995; Hughes and Lampert 1980; Hughes and Djohadze 1980; Morwood 1995:750; O’Connor et al. 1993; Rowland 1983:66), and environmental change (O’Connell and Allen 1995:861; Porch and Allen 1995:728; Rowland 1983). Several serious critiques concerned the types of archaeological data used to support the model (Edwards and O’Connell 1995:776; Hiscock 1981); the interpretation of the meaning of identified changes (Beaton 1995:798; Frankel 1988, 1991a, 1991b, Frankel 1995; Hiscock 1981; Pardoe 1995:696), and concerns about excavation methods and development of chronological sequences (Bird et al. 1997; Bird and Frankel 1991a and 1991b; Edwards and Frankel 1995; Frankel 1988, 1991a, 1991b, 1993, 1995:654; Jones 1980). Even with these debates, several underlying assumptions persisted. These were principally: 1) changes in the mid Holocene archaeological record reflected human behaviours, and 2) changes in human behaviours would be clearly reflected and easily read and interpreted from the materials in the archaeological record (see also Binford and Sabloff 1982).

Australian researchers largely underestimated the potential role of taphonomic processes in structuring, modifying and transforming archaeological records. Ongoing taphonomic research clearly indicates that 1) the kinds of broad patterns that were used as behavioural correlates are routinely created by taphonomic processes, and 2) without a taphonomic perspective these are easily misread as indicators of behavioural change.
Increases in Site Numbers, Types, and Use of New Environments

Australian archaeologists have claimed that a notable increase in site numbers and site types has occurred across the continent in the mid-late Holocene (Smith and Sharp 1993; Frankel 1988, 1993). However several researchers have identified that such variations may largely be an issue of differential site survival, as Australia has undergone vast taphonomic changes on a landscape scale over the last 60,000 years. Sites of mid Holocene antiquity are preserved, and therefore easily located, in geomorphically stable landscapes, some of which were newly created in the Holocene (e.g., some rockshelters); while large scale, geomorphic landscape changes have covered, removed, and or conflated earlier Pleistocene aged sites (Anderson 1984; Frankel 1995:654; Hall and Lomax 1996; Hope et al. 1983; Hughes and Sullivan 1981). Examples of this general issue in the Australian context have been identified in several areas of the continent and with different kinds of archaeological sites (see Frankel 1988, 1991a, 1991b, 1993, 1995, see also Clarke 1994). The effect of geological processes on the differential preservation of sites, and the effects of this on the interpretation of the archaeological record has also been recognised overseas (Stein 1987, 1993; Summerfield 1991; Waters 1988; Waters and Kuehn 1996; Wainright 1994; Watson 1969). However even when sites of mid Holocene antiquity have survived, their contents have been at least in part created, and modified by a significant range of taphonomic processes.

Broadening of the Resource Base

The argument that changes occurred in both faunal and shellfish assemblages in the mid Holocene are also more complicated. Changes in faunal assemblages in mid Holocene sites may be a reflection of several processes. Several researchers, both in Australia and overseas, have argued that the mid Holocene period especially, witnessed large-scale climatic variability (Godfrey 1989; Haworth et al. 2004; Nott et al. 2004; Schulmeister 1999; Schulmeister and Lees 1995), which resulted in changes to the distributions, availability, and reproductive productivity of many species, which was likely to have had an impact on human populations (Amarosi et al. 1996; Dodson 1989; Johnson and Wroe 2003; Kohen 1995; Strahn 1993, 1995).

The appearance of the dingo (Canis lupus dingo) in mid Holocene Australia is one taphonomic process that results in the interpretation of a diversification in the mid Holocene use of faunal species, at least in rockshelters. While Australia has had several non-human predators on faunal suites, the native dog has been the main taphonomic actor in rockshelter
sites of the mid-late Holocene. Differentiation of dual patterning of both human and canid actors has been little studied in Australia, but those that have generally argue that the dingo has made substantial contributions to faunal assemblages in the mid Holocene, contributing, removing, modifying, or overprinting human association with faunal suites (Solomon 1985; Solomon and David 1990; Walshe 1993, 1994, 1998, 1999, 2000).

The argument for the relatively late, but intense use of certain plants in regions and sites is at least a product of their poor preservation, especially in rockshelter environments. Reflecting this, plant remains often date to the last 2,000 years (Horsfall 1983, 1987a, 1987b, 1990). The argument that toxic plants are always “high cost” resources requiring substantial processing efforts has also been overstated.

**Intensity of Site Use**

The operation of a wide range of taphonomic processes can create a misleading impression of the more intensive use of sites. Sediment pH has been identified as a key chemical process affecting the preservation of older organic evidence, in most site types. However, this is particularly true for rockshelter sites, where the distribution of material often increases towards the top of a deposit, creating the impression of increases in discard in the upper portion of the deposit. In addition, variations in bone fragmentation may create the impression of the intensive use and reduction of bones, rather than being a product of canid modification, thermal modification, variations in sediment pH, which can combine to cause both specimen size reduction and apparent consistency in specimen sizes (Knight 1985; Stiner 1994; Stiner et al. 1995, Walshe 1994b).

Given the above, it is clear that pressing methodological challenges face Australian archaeologists. Given that time dependent reductive processes have operated, creating the illusion of directional change to both archaeological sites and components, how archaeologists can reliably identify and analyse patterns in the archaeological record becomes a crucial issue. These issues apply to any attempt to characterise or interpret past human changes, using any high level model, at both local and continental scales.

**Discussion of the Research Problem**

As Australian archaeology moves from characterising the archaeological record to explaining the patterns within it, it has become increasingly clear that the discipline needs to
begin building knowledge concerning taphonomy and the actors that have actively structured and modified the record we seek to interpret. However, there are considerable practical challenges. The majority of taphonomic studies from overseas contexts cannot be applied to the Australian condition as an “off the rack solution” to the problems archaeologists face. This is largely because of the diversity of taphonomic processes, the case specificity of their effects at temporal and spatial scales, and the differences in the structural characteristics of the objects affected (e.g., variations caused by animal body size or predator). As this thesis demonstrates, taphonomic research needs to be tailored to the specific research context for best results. The Australian context is genuinely different, particularly in fauna and flora, and the range of taphonomic actors and processes have not been adequately investigated.

In order to proceed, we must 1) investigate under what circumstances can the careful application of “universal” taphonomic processes investigated overseas be applied to the Australian context, 2) “datamine” relevant ecological data and carefully apply this to the archaeological context, 3) determine cause:effect relationships of the behaviours of actors and taphonomic effects on specimens under study, 4) draw on many other disciplines including palaeontology, geology, paleobotany, paleoecology, paleoentomology and forensics (see Lyman 2002b; Saul and Saul 2002), and 5) make actualistic studies of modern processes through observation and replicative experimental simulation, and application to problems encountered in the record. Such approaches were utilised in this research programme to develop preliminary methods to decipher the taphonomic processes in the Central Queensland Highlands.

Case Study of the Central Queensland Highlands

The best way to “bootstrap” taphonomic research is to focus on practical case studies of archaeological materials, integrating ecological data and experimental work as required. This approach allows us to 1) understand the gaps and issues in the available taphonomic data in Australia, 2) consider the explanatory power of “universal” taphonomic processes in Australian conditions, 3) provide a practical test of the problems archaeologists face, concerning the diversity of taphonomic processes, and the specificity of their effects at temporal and spatial scales, 4) investigate how analyses of archaeological components help the better design of experimental programmes, and 5) practically examine the gap between methodological and theoretical aspects of Australian archaeology. Three archaeological sites were used as a case study through which to explore these issues.
The Central Queensland Highlands (CQH), also known as the Central Southern Queensland Highlands (Robins and Walsh 1979:62), are located in the south-western quadrant of Queensland (Figure 2-1). The region itself extends over 84,200 km² (Walsh 1983:2). The region was formed as a result of basin uplift, and subsequent erosion worked to shape the gorge into its present appearance, forming relatively flat terrain and steep hills and gorges from escarpment retreat (Baker et al. 1993:881-893; Beetson and Gray 1993:17-18; Fielding et al. 2000) (Figure 1-1, Figure 1-2). The vegetation in the region is currently dominated by open, dry sclerophyll vegetation although local microenvironments occur within the highlands and its gorge systems.

Three archaeological sites from this region were chosen for the reanalysis: Cathedral Cave, Rainbow Cave and Wanderer’s Cave. These sites were excavated by John Beaton in the 1970s, who applied a consistent excavation and collection strategy. The assemblages contained sizeable assemblages of stone, bone and plant remains that were well preserved. Sediment samples were available to investigate site formation. The sites were generally well excavated, and detailed notes and photographs were taken at the time of excavation. These collections were well-curated in the Queensland Museum. No previous taphonomic analysis had been applied to the material from these sites. The range of archaeological evidence and adequate sample sizes were essential for the application of multiple taphonomic analytical tests on multiple lines of evidence.

The Central Queensland Highlands have been a point of origin for some of the most influential models of cultural and technological change in Australia (see Mulvaney and Joyce 1965; also Beaton 1977; Morwood 1979, 1981, 1984). Previous interpretations of the sites were influential in establishing the intensification model, with specific arguments made concerning the use of Macrozamia to support large ceremonial gatherings in the region (Beaton 1977, 1981, 1991a, 1991b; see also Lourandos 1997). A taphonomic reappraisal had the potential to contribute to these wider debates. The research conducted here should be seen as a step towards the closer integration of taphonomic approaches into mainstream Australian archaeological research agendas. This thesis demonstrates the importance of, and potential for, a positively applied approach to taphonomic analysis in the Australian context. In the process, it raises some crucial methodological issues for Australian archaeology and calls into question previous models of the CQH and the role of Macrozamia within the region.
General research questions

1. What are the key taphonomic processes operating in the sites and layers of the three analysed sites?
2. How has the archaeological evidence been modified by taphonomic processes?
3. To what extent do taphonomic processes alone account for the perceived archaeological pattern of change in the archaeological record?

Structure of the Thesis

The thesis is divided into four sections, comprised of 12 chapters. The first section, composed of two chapters, sets out the research problem (this chapter), while the second chapter introduces the study region, and discusses the previous excavation and arguments concerning the three archaeological sites. The second section, Chapters 3-6, presents an overview of taphonomic theory, the specific methods used to analyse the lithic, faunal, floral and sedimentological components of the sites, and also addresses particular issues with applying targeted taphonomic analyses to a particular region and adapting overseas methods to the Australian context. A replicative experimental programme was also conducted in this research analysing Macrozamia processing, and is presented in Chapter 7. The third section, Chapters 8-10, presents the results of the detailed taphonomic analysis of each site and discussion of implications of the taphonomic reappraisal for previous interpretations of the site. The fourth and final section of the thesis is comprised of two chapters. Chapter 11 explores the ecological and taphonomic evidence to reappraise previous accounts of the use of Macrozamia within the CQH. Chapter 12 reviews the approach taken here, indicates further research needed concerning the archaeology of the CQH, and presents a discussion concerning the future direction of taphonomic studies in Australia.
Chapter 2: Introduction to the Central Queensland Highlands

In regional analyses one is often influenced by what has been said about other sites (Gorecki 1988:165)

If a single underlying purpose of site visitation can be pointed to surely it is this, the cycad as food (Beaton 1977:190)

Before taphonomic analysis of the CQH sites begins, it is necessary to review the datasets forming the analytical sample in this thesis. This chapter focuses on the excavations, analyses and interpretations of archaeological material excavated from Cathedral, Rainbow and Wanderer’s Caves in the CQH by John Beaton in the mid 1970s. These archaeological sites, and Beaton’s interpretations of these sites, are treated as case studies through which to investigate the limits of previous analytical methods and assess the arguments that have come out of this data. These sites were also chosen as Beaton’s interpretations of the Aboriginal use of the region had extraordinary impact, and was among the first to suggest major social changes in mid-late Holocene Australia (1977, 1981, 1991a, 1991b). The key argument of Beaton was also used to support a pan-continental model of mid-late Holocene social intensification by Lourandos (1980a, 1980b, 1983a, 1983b, 1995a, 1995b, 1997).

Brief History of Research in the CQH

Five researchers between 1962 and 1980 carried out the most significant discipline building archaeological research in the CQH to date. Each of these research projects contributed important data to Australian archaeology and interpretations of Australian prehistory.

Archaeological investigations in the CQH region were initiated with John Mulvaney and Bernie Joyce’s (1965) excavation of two cave sites in the Chesterton Ranges, CQH. Their excavation of Kenniff Cave remains an important event in Australian archaeology, as it produced two significant pieces of archaeological data for the time: the first radiocarbon age determination proving Pleistocene occupation of Australia, and Mulvaney’s stone tool typology and chronology from Kenniff Cave, considered, until recently, to be a local manifestation of a wider continental trend (Beaton 1977; Lourandos 1977; cf. Bowdler and O’Connor 1991; Hiscock and Attenbrow 1998, 2004).
Both Michael Quinell (1975) and Michael Morwood (1978, 1979, 1980, 1981, 1984, 1991) have made significant contributions to understanding lithic manufacture in the region. In addition, they both analysed changes in rock art in the region. Today, archaeological research is continuing within this region (Godwin et al. 1999), and in similar environments to the east (Lilley et al. 1998, 1999).

John Beaton conducted archaeological excavations in the region as part of his doctoral research at the Australian National University. Beaton’s research was inspired by the prior research of Mulvaney and Joyce (Beaton 1977). Beaton aimed to “broaden the prehistory of the region” (Beaton 1991a:3), and excavated three large rockshelter sites in the CQH, which he saw as “examples of the rarest but individually richest sites” which he located in the region (Beaton 1977:27). These sites offered dateable assemblages of stone artefacts, the sequences of which could be compared to those from Kenniff Cave, and faunal material could inform about site economy (Beaton 1977:27).

One of the most significant contributions of Beaton’s research in the CQH was the argument that occupation of the region was related to ceremonial activities, which were supported by the toxic cycad, Macrozamia moreii. This argument was also to become important in models of mid-late Holocene social and economic change (Lourandos 1983a, 1983b, 1985a, 1985b, 1995a, 1995b), and wider interpretations of the mid Holocene use of other toxic plants in Australia (Horsfall 1983, 1984, 1987a, 1987b, 1996; see also Cosgrove 1996; c.f. Asmussen 2003). The following section describes the sites and summarises the archaeological data on which Beaton’s model was based.

**Cathedral Cave**

*General Environmental Characteristics*

Cathedral Cave is located in Carnarvon Gorge (Figure 2-1, Figure 2-2). Carnarvon Gorge itself is located in the southern portion of Carnarvon National Park, bounded on the north by the Consuelo Plateau, forming part of the Great Dividing Range (1,200 m asl) and on the south by the Carnarvon Range (Quinell 1975:2) (148° 4S, 148° 16S and longitude 24° 54S and 25° 8S). The gorge itself is 32 km long, with high (182 m) vertical sandstone walls. Carnarvon Gorge forms part of the Carnarvon Range, stretching in a NW-SE direction along the NW margin of the Surat basin (Beetson and Gray 1993).
Site Description

The cave itself is situated along the bank of Carnarvon Creek, near the junction of Boowinda Creek Gorge (Figure 2-3). Cathedral Cave is a large shelter, 82 m long and 30.5 m wide formed by cavernous weathering. The north-facing cave is situated 5 m above and 60 m distant from Carnarvon Creek (Figure 2-4, Figure 2-5). The useful floor area was calculated to be c. 670 m², defined by the shelter walls and the dripline, after the removal of areas covered by large block falls of parent shelter material. The shelter floor exhibited a gentle incline in slope at the western end, and a large area of sandstone block fall was located at the eastern end, rising 10 m in height above the shelter floor. At the time of Beaton’s excavation in 1975, the floor of the cave, and the gorge generally, was surrounded by dry schlerophyll forest and stands of M. moreii, one of which grew at the western end of the shelter (Beaton 1991b:37-8). Local catchment drainage patterns directed channel runoff into Carnarvon Gorge via Carnarvon Creek.

Excavation Procedure

Nine excavation units were placed in the site, five were located towards the back of the shelter and four at the front of the shelter (see Figure 2-6, Figure 2-7). The units covered 17.5 m² of the floor area, removing 27 m³ of the deposit (approx 0.5%) (Beaton 1991b:41). Fourteen stratigraphic levels were identified in the site, four of which contained cultural material (Figure 2-8). The excavation reached a maximum depth at the back of the shelter in Unit 3 of 4 m; sediment was sieved using a 3 mm mesh. Layers were excavated following natural stratigraphy. A radiocarbon determination was obtained from one of the last (non-basal) strata to be excavated, indicating occupation occurred by 3,560 ± 80 BP (ANU-1762). Differences in sediment pH across the site and with depth are unknown as these were not taken at the time of excavation. The stratigraphic levels of Cathedral Cave document a repeated history of fluvial events. The sediment record suggested to Beaton that the site was not constantly used, as occupation events were separated by several hundred years, and that occupation horizons were shallowly spread throughout the large floor area of the cave.

Lithic Specimens

Over 6,000 lithic artefacts were excavated from the site. Of these, 454 were classified as “implements” following a typological analysis (Beaton 1991b:59). The majority of implements were identified as scrapers, composed of very fine scrapers (40%), side scrapers
(20%) and amorphous scrapers (15%). Beaton defined 99 side scrapers, eight disk scrapers, 27 notch scrapers, 27 end scrapers and 171 very fine scrapers. Also, there were 11 cores, 66 amorphous flakes, 20 backed blades, 15 burren chisels and 11 tulas, two hammerstones and 35 pieces of grindstone (Beaton 1991b:60, Table 9). Beaton interpreted the stone tool assemblage and suggested that the site was occupied irregularly.

Faunal Specimens

Beaton described the preservation of faunal material at Cathedral Cave as excellent, although highly fragmented. A preliminary species identification, based on dental and cranial specimens, was carried out by Archer and van Dyck, then at the Mammalogy Department of the Queensland Museum (Beaton 1977:85, 1991a:27). They provided a list of species present in levels of the site, but did not provide minimum numbers of individuals (MNIs). Thirty species were identified. These included fish (Tadanus sp.); lizards (Amphibolurus barbatus, Chlamydosaurus sp., Gekkonid, Tiliqua scincoides, and Ergenia cunninghami); python (Morelia spilota); native cat (Dasurus hallucatus); marsupial mouse (Antechinus flaviceps); bandicoots (Perameles nasuta, Isoodon obesulus and Isoodon macrourus); possums (Trichosurus vulpecula and Pseudocheirus peregrinus), glider (Schinobates volans); potoroo (Potoroid); rat kangaroos (Aepyprymus rufescens and Betongia sp.); pademelon (Thylogale sp.); wallabies (Wallabia bicolor, Petrogale sp.), Macropods (Macropus sp., M. paryii, M. agilis, M. giganteus, M. robustus); water rat (Hydromys chyrogaster) and the little flat bat (Tadaria cf. planiceps). Data concerning faunal species was presented as a list with the number of identified specimens per level and unit (Beaton 1977, 1991b:76, table 20). The weights and comparative percentages of postcranial material was also presented in general categories of small mammal, large mammal, bird, fish, reptile, and unidentified, broken down within these categories as burnt or unburnt (Beaton 1991b:76, table 20). A small amount of freshwater mussel shell (Velesunio ambiguus) was also identified from the deposit, with weight and provenance given (Beaton 1991b:78, table 21).

Beaton argued, based on interpretations of the cranial remains, that there was a broad exploitation of large and small mammals at the site, and that birds, possibly ducks (Dendrocygna sp.) and scrub turkeys (Alectura lathami) contributed significantly to the diet (Beaton 1991b:81). The exploitation of the gorge and plateau, as well as a range of microenvironments within the gorge was suggested (Beaton 1991b:77, 81). The local environment and species distribution in 1975 suggested a 4-5 km foraging radius around the
site was used to search for prey (Beaton 1991b:77). The condition of the faunal material suggested that bones were broken at both ends by humans in the removal of marrow (Beaton 1991b:81).

Beaton identified over 123 bone tool specimens, made from a variety of elements at Cathedral Cave. These included 32 mandibles, the incisors of which Beaton suggested were used as wood engravers, and 91 tools made from long bones from different species of wallabies. These were classified as spatulate, fibulate, bi-point, tubular, flaked, ground or polished bone tools. These specimens were argued to have been used in the manufacture of "soft goods" such as cloaks (Beaton 1977, 1991b:68, Table 19). Bone tools were identified by striations, use polish or damage, but not necessarily all three criteria (see Pickering 1979, 1980; Webb 1987, see also Ramis and Alcover 2001). The majority of the tools derive from the upper three levels of the site, dated to the last 2,300 years (Beaton 1991b). However the bone tools made on Macropod long bones are not currently present in the collection.

Macrobotanical Specimens

Although their abundance was difficult to estimate due to the fragmentation of the shells as a result of carbonisation, Beaton estimated the abundance of *M. moreii* seeds in Cathedral Cave to be approximately 500 per m³ (Beaton 1977:129, 1991b:81). Beaton claimed that *M. moreii* seed shells were recovered from all occupation horizons of the site and from all excavation units, and were burnt and fragmented in the manner observed at Rainbow and Wanderer’s Caves. Beaton suggested that people carried large numbers of unshelled seeds and roasted them in the site. One *M. moreii* plant grew on the dripline at the western end of the shelter, and larger populations of *M. moreii* were located 5-15 km downstream from the cave and on the plateaus (Beaton 1991b:81). Beaton suggested that there was ample water available in Carnarvon Creek for leaching out the toxic components of the kernels (Beaton 1991b:82).

Taphonomic Comments

Cathedral Cave was considered by Beaton to have had a complicated depositional history over the last 4,000 years. Beaton found the stratigraphy of the site was often difficult to interpret. Occupation events appeared to be separated by several hundred years, and there was also evidence that floods had at least deposited sediment in the shelter. The exact nature
of fluvial disturbance at the site was unresolved by Beaton (Beaton 1991b). Although some areas of the site appeared to contain evidence of bioturbation, no vertical movement of materials was identified (Beaton 1991b:52). The native dog (C. lupus dingo), owls or other predatory birds were raised as taphonomic agents. Beaton argued that very few of the faunal elements were considered to be “naturally” incorporated into the deposit. Ultimately all faunal elements were considered to be the prey species of the Aboriginal occupants of the cave (Beaton 1991b:75, 81).

Possible preservation biases of the macrobotanical material were also considered. Beaton stated that the use of plant foods at the site could not be documented in detail even though they may have contributed about 70% of the diet, because plant remains did not preserve well in soil matrices derived from sandstone exfoliation. However Beaton claimed that there were abundant remains of the seed shells of one plant, M. moreii. Its preservation in the sediments was due to its thick, tough seed shell and the fact that most of the shells had been carbonised, making them less subject to chemical decomposition (Beaton 1991b:49).

Beaton’s Interpretations of the Occupation of Cathedral Cave

Cathedral Cave was considered by Beaton to be an ideal base camp, located next to fresh water. He argued the cave was used as a temporary shelter, with irregular occupation events, often separated by several hundred years, suggesting that the site was used as an “outstation” rather than a central camp (Beaton 1991b:82).

The occupation horizons were characterised as shallow midden deposits (10 cm depth) spread throughout the large floor area of the cave. Beaton argued that these were deposited by 50-100 people for one to two weeks at a time. Beaton suggested population and temporal restrictions may have been a factor limiting occupation as he considered the gorge a food poor environment, lacking the resources (meat, plants, fish and firewood) to support large numbers of people for longer than two weeks (Beaton 1977:188). Beaton considered that 15 people would deplete the gorge resources within a reasonable (1 km) foraging distance from the site. A group of 50-100 people, which he believed would be necessary to deposit the remains, could not subsist off the gorge resources for more than one or two days, unless they carried food with them or were making use of a seasonally available resource. He suggested that the caves were used in response to an irregular glut of cycad seeds, which allowed the congregation of large numbers of people (Beaton 1977:190). Beaton reasoned that Cathedral
Cave and Carnarvon Gorge more generally might have been important locations for Aboriginal social interaction (Beaton 1981:49).

Rainbow Cave

General Environmental Characteristics

Rainbow Cave is located within the Carnarvon Ranges on Wallaroo Station, at approximately 650 m above sea level (asl). The site overlooks the Arcadia Valley 325 km in the eastern distance, the Expedition Range in the eastern distance, and is 6 km south of Wanderer’s Cave (Beaton 1977:66) (Figure 2-1). At the time of Beaton’s excavation in 1975, the vegetation in the local area around the cave was dominated by mixed dry forest, with spotted gum and thick vine scrubs on the steep eastern slope to the site. *M. moreii* was patchily distributed in the area (Beaton 1977:66, 1991a:5). The nearest water sources to the site were Brown River, 1 km to the east, and Corella Creek, 1 km to the southwest, however access to either was considered difficult due to the terrain. It was suggested that other sources of water could be found in eroded rock holes or dug from pits after good rainfalls (Beaton 1991a:5).

Site Description

The oxidization of ironstone beds in the parent rock of the shelter (Moolaymber Formation) has formed broad coloured bands at the top giving the shelter its local name (Beaton 1977:67). The shelter has a northeastern orientation and has been eroded to form a cavern (Beaton 1977:81; Beetson and Gray 1993; Mulvaney and Joyce 1965:152) (Figure 2-9). The shelter is an 83 m long and 6 m narrow space with a maximum vertical overhang of 25 m (Beaton 1991a:8). The back wall rises to form the high and gently arched wall and shelter roof (ceiling) (Beaton 1977:67, 1991a:5). The floor of the shelter is gently sloped, and falls 3 m from its southern to its northern end (Beaton 1977:67, 1991a:8) (Figure 2-8). The useable floor area of the shelter (defined by the north-south running dripline and the shelter walls) was estimated to be approximately 500 m² (Beaton 1977:67). Differences in the size of sediment particles were noted between the north and east of the dripline area of the shelter and other areas of the site, suggesting the removal of finer sediment sizes (Beaton 1977, 1991a). As the shelter has eroded from a vertical sandstone wall, pedestrian access is available from the northern end of the range, and steep slopes occur to the east and west of
the site (Beaton 1977:66, 1991a:5). A variety of trees grew 2-3 m west of the dripline and on
the slopes outside the shelter at the time of excavation.

**Excavation Procedure**

Beaton laid a grid system over the site and ran a base line oriented 10° west of magnetic
north. Two 1 m by 2 m excavation units were excavated at the site, the names of the units
corresponding to their location on the site grid, designated 14N1W and 14S1W (Beaton
1977:69, 1991a:8) (Figure 2-10). The deposit was excavated in 5 cm units, and all material
was sieved through a 3 mm (1/8") sieve. A sediment sample was excavated from each 5 cm
level from the south wall of 14S1W (Beaton 1991a:8). Variations in stratigraphy and the
depth of the deposit were assessed through the excavation of six soundings measuring 0.25
m², located at 34N-1E, 15 N 2.5E, 6N-3W, 8S-1W and 22S-1W (Beaton 1991a:8) (Figure 2-
10). However no depths of the soundings, or their composition relative to the excavation
matrix were given in published or unpublished papers.

Six stratigraphic units were identified in 14S1W resting atop of a basal layer of decomposed
sandstone bedrock. The excavation unit reached a depth of 70 cm at its deepest extent
(Figure 2-11, Figure 2-12). Fieldnotes suggest that the ash lenses in the upper deposit had
pH levels of 6-7.5 while the pH in the remainder of the matrix averaged 4.0-5.0. Faunal and
flaked stone artefacts were plotted on graph paper at the end of each five cm level for both
units before their removal (Beaton 1977, 1991a:8). Five stratigraphic units were identified in
unit 14N1W (Figure 2-13), and the excavation reached 55 cm at its deepest extent.
Differences in the pH in this unit of the site were apparent. The pH at 14S1W was constant
between 7.0 to 7.5 in the upper 40 cm, while it dropped to 7.0 and 6.5 at bedrock (Beaton
1991a:9), while the average pH in the upper portion of the deposit in 14NIW were between
6.5 at the surface and 5.5 and 6.0 between 15-25 cm depth.

**Cultural Materials**

The excavation of Rainbow Cave revealed floral, faunal and lithic material, with the lithics
being analysed in finer detail than the other archaeological components. Data concerning
Beaton’s sedimentological analysis are not discussed here due to methodological problems,
which affected the results of the grain size analysis and subsequent interpretations of site
formation history (see Webb 1992). The excavation reached a maximum depth (bedrock) at
55 cm, and the earliest occupation at the site was determined at 3,600 ± 100 BP (ANU-1521) at 40 cm below the surface of 14N1W (Beaton 1991a:10).

**Lithic Specimens**

A total of 517 lithic specimens were excavated from both units at Rainbow Cave. According to Beaton’s typological analysis, 47 of these were identified as implements, including five side scrapers, one disc scraper, three notch scrapers, one end scraper, five amorphous scrapers, one burren chisel, one tula, 20 very fine scrapers, three backed blades and seven pieces of ground stone. The remainder of the lithic component was considered to be waste (Beaton 1991a:11).

**Faunal Specimens**

The faunal remains were described as being well preserved, although highly fragmented in the upper levels and very friable and poorly preserved in the lower levels. Three Macropod species were identified by Archer and van Dyck as wallaroo (*M. robustus*, and *Macropus* sp. unidentified) and rock wallaby (*Petrogale pencillata*) (Beaton 1977:71), although no further details were available.

**Macrobotanical Specimens**

Beaton argued that the “most abundant cultural material” in the site was the humanly broken shells of *M. moreii*, which were found throughout the sedimentary levels. Beaton stated that the excavation screens, filled with about 2 kg of sandy matrix, would sieve out “dozens to hundreds” of *M. moreii* shell fragments (Beaton 1991a:11). The overall quantity of nut fragments was conservatively estimated to be about 400-500 nuts per m³. The north and south units and the various sounding tests all had very similar amounts of broken Macrobotania seed shells, suggesting the deposit was “homogenised”(Beaton 1991a:12). The preservation of the fragments varied with depth and the degree of carbonisation (Beaton 1991a:11). Beaton described the Macrobotania seeds as being roasted in significant quantities, with approximately 50% of the nutshells slightly to highly carbonised, suggesting to Beaton that they were burnt after the kernel was removed (Beaton 1977:85, 1991a:27). Carbonised kernel fragments also occurred in the deposit but were rare. Beaton suggested that small wooden batons could have been used to open the nuts, a method used by the Gidjingali of the Blyth River in northern Arnhem Land (Meehan 1982, Meehan and Jones 1977) but no
wooden batons were found in the excavation (Beaton 1991a:12). Shells with rodent toothmarks were found on the surface of the deposit and around the site generally. Beaton stated that he did not identify rodent gnawed specimens from the excavated material, but suggested that these could easily occur in small numbers and may have been missed (Beaton 1977:72, 1991a:12).

Beaton’s Interpretations of the Occupation of Rainbow Cave

Beaton did not consider Rainbow Cave to be a base camp because of a lack of easily obtainable water, also arguing that the placement of the site in the local environment made the transport of prey difficult. He suggested that this site was conveniently placed for travelling to different parts of the surrounding habitat. Beaton suggested that small numbers of stone implements were made during “maintenance or extractive activities” during occupation events at the site. Faunal remains indicated that small numbers of marsupials were caught and consumed in the site, suggesting an opportunistic capture of animals by Aboriginal occupants who went to the site for a different purpose. Plant remains at Rainbow Cave suggested that the exploitation of Macrozamia groves near the site was an important reason for the use of the site in the latter half of the dry season late in the year (Beaton 1977:187).

Wanderer’s Cave

General Environmental Characteristics

Wanderer’s Cave is situated on the spine of the Carnarvon range at 640 m asl. The site is located on the northern boundary of Wallaroo Station, and the southern boundary of Warinilla Station, and is located 6 km North of Rainbow Cave (Figure 2-1). At the time of Beaton’s excavation in 1975, tall and open spotted gum or ironbark forest with a grassy understory dominated the vegetation in the local area around the cave. *M. moreii* plants were “thickly distributed”, with approximately 60 plants growing within 100 m of the cave entrance (Beaton 1977:77, 1991a:19). Local catchment drainage patterns direct runoff to the Dawson and Comet Rivers (Beaton 1991a:18, 1977:77). Beaton noted that the nearest water source were the intermittent pools in Spring Creek, 2 km distant and 300 m lower in elevation (Beaton 1977:77, 1991a:18).
Site Description

The westward facing cave is situated along a sandstone range running 110 m east-west and 15 m north-south (Figure 2-14, Figure 2-15). The top of the sandstone ridge lies approximately 4 m above the shelter (Beaton 1991a:19). The cave was weathered on its outer surface and the interior contains tubular weathering canals (Beaton 1977:78, 1991a:19). Beaton noted that the steep slopes in the vicinity made access to the cave from the west and the north difficult, but access along the south and east was easier (Beaton 1977:80, 1991a:21). There was no build-up of sediments at the front of the shelter, the slope being quite steep at approximately 30° (Beaton 1991a:22).

Beaton estimated the total floor area of this small enclosed cave to be 171 m². However, when taking into account areas of accumulated roofall and areas of low ceiling height, the cave has a useable area of 70 m² (Beaton 1991a:20) (Figure 2-16, Figure 2-17). The shelter floor was comprised of weathered parent lower Jurassic Precipice Sandstone (Beaton 1977:81; Beetson and Gray 1993; Mulvaney and Joyce 1965:152). The floor exhibited a slope of 3-5° that dipped toward the east (Beaton 1977:80) (Figure 2-18). The dripline at the front of the shelter was 12 m long, located across the western entrance at the mouth of the shelter (Beaton 1991a:22). Beaton noted that the walls and ceiling of the cave had black stains which were thought to be smoke staining from campfires. Areas of red, yellow and white ochre were also noted on the shelter walls (Beaton 1991a:21).

Excavation Procedure

A grid system, oriented on magnetic North was laid out over the cave and a 1 m by 2 m excavation unit (pit) called 3N4E, was excavated in 5 cm arbitrary levels, with materials sieved through a 3 mm (1/8") sieve (Beaton 1977:82, 1991b:23). A sediment sample was excavated from each 5 cm level from the eastern wall of the pit (Beaton 1991a:23). Five soundings (0N1W, 1S2E, 3S5E, 7N5E and 4N8E, each 0.25 m²) (Figure 2-17) were made in the cave, the stratigraphy, colour, texture and material composition of which was found to be consistent with that identified from the main excavation (Beaton 1977:83, 1991a:24). Basal depths of the soundings themselves varied from 16-36 cm, the excavation unit was located in the deepest area of the site, having a maximum depth of 50 cm (Beaton 1991a:24). Six stratigraphic units were identified in the site (Beaton 1991a:23) (Figure 2-19). The three basal strata were highly acidic at 4.5-5.0, in comparison to the upper three levels where the pH ranged from 6.0-8.0 (Figure 2-19).
Cultural Materials

The excavation of the cave revealed floral, faunal and lithic specimens. The lithic component was analysed in greater detail than the faunal or floral components. Data concerning Beaton's sedimentological analysis are not discussed here due to methodological problems that affected the results of the grain size analysis and subsequent interpretations of site formation history (see Webb 1992, see also Chapter 3). The excavation reached 50 cm depth, and an in situ carbon sample was obtained from 35-39 cm, the lowest level from which a conventional determination could be obtained. This sample returned a determination of 4,320 ± 80 BP (ANU-1552). An in situ sample was also submitted from "the top of the 5-10 cm level", at approximately 7 cm depth, returning a determination of 820 ± 70 BP (ANU-1539) (Beaton 1977:83). An inscription on the back of the shelter wall provided a minimum date for European visitation at the shelter of 1906 (Beaton 1991a:18).

Lithic Specimens

Over 330 lithic specimens were excavated from Wanderer's Cave. Beaton conducted a typological analysis and identified 31 implements, including seven side scrapers, two end scrapers, one broken scraper, one backed blade, one tula, one burren, three fragments of ground stone and 15 very fine scrapers. The majority were made using silicious materials (Beaton 1977:84). Two artefacts retained hafting gum (one burren chisel and one very fine scraper). The majority of the lithic artefacts (N = 266) were considered debitage.

Faunal Specimens

Preliminary species identification based on dental and cranial specimens were carried out by Archer and van Dyck (Beaton 1977:85, 1991a:27). A range of Macropods (M. robustus, M. dorsalis and M. paryii, and two unidentified to species level), wallabies (Wallabia sp., W. bicolour, Petrogale sp., Thylogale sp.), possums (T. vulpecula, P. peregrinus), bandicoots (P. nasuta and Isoodon sp.), rat kangaroo (Bettongia sp.), glider (S. volans) and quoll (D. hallucatus) were identified (Table 2-1). Shell of the family Camaenidae was also identified. From these data Beaton made the basic assertion that small and large marsupials living near the site were caught and consumed at the site, reflecting opportunistic capture of the species (Beaton 1991a:27, 31). As very few specimens were complete enough to be identified to
species, the majority of the faunal material, which was described by Beaton as broken and burnt (1977:85, 1991:27), was not analysed.

*Macrobotanical Specimens*

Beaton stated that the humanly opened seeds of *M. moreii* were the most abundant and important organic remains in the deposit, stating that “the entire deposit seems to be a midden of Macrozamia shells” (Beaton 1977:86). Although no data concerning the total number or weight of Macrozamia specimens was presented, Beaton estimated their abundance at about 500 per m$^3$ (Beaton 1991b:81), and evenly distributed in all sampled areas of the site (Beaton 1977:86). The “majority” of the broken shells displayed a range of carbonisation extents but “at least half were burnt/roasted” (Beaton 1977:82, 1991a:23). Some of the shells were so carbonised that he suspected that they were not burnt during roasting of the nuts in their shells, instead some may have been incidentally burnt some time after the nut had been removed, roasted or not (Beaton 1991a:27, 1977:86). Beaton noted that high quantities of burnt wood also co-occurred with high densities of Macrozamia in the site, indicating that “nuts were roasted in significant quantity” (Beaton 1977:85, 1991a:27). Beaton suggested the use of Macrozamia seeds occurred late in the year, when the occupants went to the sites for a “different purpose”. The exploitation of *M. moreii* was of great importance in the sites and was argued to be linked to ceremonial activity in the region (Beaton 1977:187).

*Taphonomic Comments*

Beaton made several comments concerning possible taphonomic processes operating at Wanderer’s Cave. He suggested that vertical post depositional movement of approximately 10 cm may have been “very likely” (Beaton 1977:85). Beaton also noted that half way through the deposit the preservation of uncarbonised material decreased, suggesting that over 4,300 years some biological and chemical decomposition had occurred (Beaton 1977:88, 1991a:29).

*Beaton’s Interpretations of the Occupation of Wanderer’s Cave*

Beaton considered the environmental context of the site, its size and the archaeological data to suggest a model of site use over the last 4,000 years. Wanderer’s Cave was not considered to be a base camp due to its distance from water sources and because the cave was
considered too small to support more than 12 people at a time (Beaton 1977, 1991a). As a result, the site was suggested to be occupied by small parties of people as a stopover point while travelling to and from other locations of the region. Stone artefacts were made at the site, with small numbers of flakes used in “maintenance or extractive” activities. Occupation occurred late in the year, linked to ceremonial cycad activity in the region (Beaton 1977:187). Beaton also concluded that evidence from Wanderer’s Cave generally agreed with the findings of Mulvaney and Joyce (1965) for Kenniff Cave and The Tombs, and Morwood’s (1978, 1979, 1980, 1981, 1984) interpretations of stone artefact chronologies.

Regional Model for Occupation: the Role of *Macrozamia moreii*

Beaton argued that an unexpected, but consistent theme of the occupation of the three rockshelter sites was the use of *M. moreii*, as the remains of fractured and charred shells were found in high densities in each occupation layer in each site. Beaton asked two questions concerning the late occupation of the uplands: why was the plant food so important to site occupation and what did site use in the uplands tell us about wider problems in Australian prehistory (Beaton 1977:192).

*Why was Macrozamia Considered Integral in CQH Occupation?*

Beaton argued that the ecology of Macrozamia held the key to the occupation of the region. Beaton identified several important features of the Macrozamia plant: Macrozamia grew in clusters, producing seeds on a cone in the dry season. The only available research into coning frequency at the time of his research indicated that the production of seeds may take up to 18 months in some species (Brough and Taylor 1940). Beaton used Harris’ (1974) data on a plot of cycads in North Queensland, and his own fortuitous observance of differences in quantities of seeds between an unburnt and burnt plot of Macrozamia in NSW (1977, 1982), to argue that seed production may be initiated, quickened, or synchronised in groves, by the application of a “gentle burn” (Beaton 1977:167).

The quantities of Macrozamia in these sites led Beaton to consider the circumstances under which these seeds could be eaten. The apparent quantity of Macrozamia remains became the key evidence behind Beaton’s interpretations of the use of the sites and the region in the mid-late Holocene (4,000 BP to the present). Beaton researched the use of cycads as documented in overseas and Australian ethnographic literature, which indicated that there were generally three contexts under which cycads were eaten: in times of starvation, in
everyday use, or in ceremonial use (Beaton 1977:162). These conditions were considered for the CQH context.

Starvation use of *Cycas* sp. was documented in the overseas literature, although descriptions of cycad use were largely confined to oceanic islands where cyclones devastate the environment, or during World War II. Beaton found no ethnographic reference to the use of cycads as a starvation food in Australia, but suggested that if there was a place that Australian hunter-gatherers needed to rely on them it would have been on the northern islands and tropical coasts (Beaton 1977:163). Beaton argued starvation was not a significant threat on continental landmasses. In the case of the upland rockshelters it was argued to be most unlikely that archaeological deposits spanning several thousand years could result from the use of the plants in times of starvation. Thus the starvation scenario was considered to be an infrequent phenomenon and “confidently rejected” as an explanation for the apparent densities in the sites (Beaton 1977:162-3).

The literature review indicated to Beaton that the “possibility that the use of cycads were a staple in parts of Australia cannot be dismissed” (Beaton 1977:164). The mundane or everyday use of cycad seeds was widespread across a range of communities around the world, and made a valuable contribution to the diet (Beaton 1977:163). The Australian ethnographic literature and historic records also documented the use of cycads as a staple food and Beaton gave several examples: central New South Wales in winter (Lampert and Sanders 1973: table 1 in Beaton 1977), along the central eastern coast (Petrie 1904) and north into Cape York Peninsula (Thozet 1878), the west coast of Australia (Grey 1841:295) and Arnhem Land (Thomson 1949b). There was also some evidence that cycads were the preferred food in times of plenty (Tindale 1925:76). The desert was the only place where mundane use of cycads was not documented (Beaton 1977:164; Webb 1973:294). However Beaton suggested the term “staple” was misleading and that due to the seasonal nature of the seed production it could only be a major part of the diet at certain times of the year, although he also noted that the seeds could be stored (Beaton 1977:164).

Beaton concluded that the prehistoric mundane use of cycads was “a certain reality” but it had mostly “mundane implications” (Beaton 1977:195). Beaton considered that the mundane use of the cycad could have occurred in the CQH as the kernel provides an important source of starch in the late dry season, a period of general scarcity of vegetable food before the early summer rains which stimulated fresh growth of other plant resources. However Beaton
was uncomfortable with this explanation, stating that mundane use did not easily fit the archaeological evidence from the sites:

“these facts would support a straightforward explanation for the use of these sites, but they do not fit the archaeological data. Why should there be a period of intensive use of a site and then none at all for perhaps several hundred years? Why were there not more rockshelter sites with similar deposits near other cycad groves? Why did the use of the sites begin at 4,500 years BP if the resources had been available earlier and man lived in the area, as implied by the use of Kenniff and the Tombs? It is possible that cycads were used when in season and as a part of the daily food quest. But this mundane use does not comfortably fit the archaeological data” (Beaton 1977:194).

Beaton came to argue that “the archaeological evidence is not unequivocal but it is highly suggestive” of the connection between Macrozamia nuts as a communion food in ceremonial activity (Beaton 1981:49). He argued that there is ethnographic and ethnohistoric evidence that Australian Aborigines exploited the “abundant” yields of cycads as an integral part of large ceremonies, which involved “hundreds of individuals” (Beaton 1977, 1983, 1991a, 1991b). To support this argument he cited the Kunapipi ceremonies of the Northern Territory (Spencer 1914; see also Berndt 1951; Harvey 1945:191) and more recent research conducted on ceremonial cycad use at the time of Beaton’s research tenure (Morphy pers. com. to Beaton 1977; Meehan and Jones 1977 Appendix iv, in Beaton 1977:165-166; Meehan and Jones 1989). He also suggested that the yields of seeds from plants suggested a co-operative collection and processing effort, involving many more people than the small economic unit of the Australian “band” (Beaton 1977:172). The ceremonial use of cycads was considered to be “peculiar to Australia”, the deposits reflecting subsistence activities directed toward supporting unusually large gatherings of Aborigines (Beaton 1977:194). Beaton argued that ceremonies were timed to take advantage of local cycad abundances used to support large groups of people:

“Could it be that the system of large ceremonies has been archaeologically expressed in the upland shelters, several thousand kilometers and several thousand years from where it is still practised today?...There is no single crucial piece of evidence from the upland archaeological sites that identified the shelter and cycad use as reflecting communion activities but the circumstantial evidence is highly suggestive. Cycads are not best exploited in a mundane manner, the investment in energy is high, and production time is long. Crops are not annual but may be synchronised by firing the grove...If this is done Productivity may ensue to embarrass a single band of Aborigines...if an unusually large gathering of Aborigines had been sustained by cycads in a rockshelter the dense remains would have a better chance of being preserved in an acidic environment than they would be if a small group deposited the same number of remains over a longer period of time” (Beaton 1977:195).
Beaton considered that this “hypothesis had enough circumstantial support to merit full consideration”. He then suggested that the use of cycads as a communion food raised important questions about wider problems in Australian prehistory: the significance of the most important change in the archaeological record of the continent; the change marked by the onset of the small tool tradition (Beaton 1977:195). At the time, the Australian small tool tradition was considered to be a pan-continental industrial change (see Hiscock 2002; Hiscock and Attenbrow 1996, 1998, 2002, 2003, 2004).

The Role of Cycads in the Prehistory of the Central Queensland Highlands and Beyond

Beaton argued that the use of cycads in the uplands was an archaeological expression of an emerging pattern of important Aboriginal social interactions widespread at the time of early European contact, which was still practised in some areas in the 1970s. These ceremonies were argued to help tie together social and economic relations and fulfil important ritual obligations between neighbouring groups, but other interactions also took place at the same time: exchange of information, technology, and ideas, and the making of alliances and marriages. Beaton considered the exchange of these elements were important aspects of large-scale ceremonies (Beaton 1977:196, 1981:49).

Beaton argued the planned exploitation of the super-abundances of some single resources facilitated the association of otherwise more disparate groups (Beaton 1977:197). The seeds were also found in other excavations in the CQH (at The Tombs and Kenniff Cave), and were also identified in archaeological sites in the Blue Mountains of New South Wales, the south coast of NSW, in northern NSW and in the Northern Territory (Beaton 1977:197-198) between 5,000-2,000 BP. Beaton argued that if cycads were used in this way then a network of ceremonially based population gatherings would be correlated with the distribution of cycad plants. However he suggested that other resources that were more limited in distribution than cycads may have served the same communal function, including Bunya pines (Auracaria bidwillii) and Bogong moths (Argrotis infusa)(Beaton 1977:198; Flood 1980, see also Flood 1983, 1990). Historical records documented that tribes travelled from up to 20 km away to attend feasts of Bunya nuts, and from 80-160 km away to attend feasts of Bogong moths. Beaton saw parallels between harvesting Bogong moths and harvesting cycads in the CQH, believing claims that Bogong moth hunting began around 3,000 BP to 4,000 BP (Beaton 1977:199; Flood 1980).
Discussion: the Impact of Beaton’s Model on Australian Archaeology

Beaton’s argument for the ceremonial use of cycads and other associated mid-late Holocene change had a significant impact on interpretive models in Australian prehistory. Several archaeologists used Beaton’s arguments for social and technological change in the mid-late Holocene in the Central Queensland Highlands. In particular, Lourandos (1980a, 1980b, 1983a, 1983b, 1997) drew on Beaton’s arguments, along with other arguments and evidence to support his claim for socially driven economic intensification across the Australian continent over the last 4,000 years. These included:

1. that increasing occupation occurred throughout the late Holocene in marginal resource zones (wetlands, peripheral rainforest and highlands) (Lourandos 1983a:87).
2. that increasing complexity of site forms and their economies also took place in the late Holocene. Base camps with a wide range of semi-sedentary resource strategies were established in marginal areas (earthmounds in wetlands, open inland sites, coastal shell middens) (Lourandos 1983a:88).
3. a trend from short term or seasonal use of sites to long term or annual usage: that individual sites were more intensively occupied through time and there was increased establishment of new sites through time (Lourandos 1983a:82).
4. that these trends are associated with ceremonial events (Lourandos 1983a).
5. that the complex semi-sedentary and resource intensive settlement pattern observed from the ethnographic sources can be demonstrated archaeologically (Lourandos 1983a:82, 88).

The majority of Beaton’s arguments concerning the mid-late Holocene of the CQH fitted perfectly within Lourandos’ larger continent scale model. Specifically, Beaton’s arguments were used to support Lourandos’ major claims including increasing occupation of relatively unused resource zones, paraphrasing Beaton’s arguments by stating a “marked intensification of Aboriginal use of the region beginning about 4,000 to 5,000 years ago” (Lourandos 1997:142; quoting Beaton 1977:192). He also restated Beaton’s estimates of Macrozamia density in these sites: “Macrozamia moreii were found in large quantities in the CQH rockshelter sites, dated from around 4,300 BP and densities of husks, shells and seeds of between 400-600 per m³ were recorded at all three sites”. Lourandos argued that these indicated an intense processing and use of the cycad, a “phenomenon”, occurring between 4,300 BP and the present (Lourandos 1997:143).

Although Beaton believed that a laborious leaching of the toxic components of the nuts was required, recent evidence suggests this is only the case with fresh seeds (Beck 1985, Beck et
al. 1988). However, based on this idea, Beaton suggested that once the “leaching tool” was added to the tool kit, it “opened up possibilities for expanding the economic base as there were appropriate plants, it would have population, adaptation, and survival value” and that its “its presence in prehistory could mark an intensification of habitat use that would have parallels in other major shifts in extractive economy, such as the adoption of horticulture” (Beaton 1982:142, quoted in Lourandos 1997:142). However Lourandos noted recent evidence indicating that toxic properties of cycad seeds could be leached out by natural processes, such as through the weathering of fallen nuts. Therefore nuts could have been in use long before the leaching techniques were developed. Lourandos advanced the argument that the time consuming processing methods should be viewed as a clear indication of intensification of production (Lourandos 1997:143). Macrozamia seeds excavated from a rockshelter site in Western Australia dated to 13,000 BP (see Smith 1982, 1996) also suggested to Lourandos that the use of the seeds could have a long antiquity, and that the use of cycads and leaching methods might have dated to the terminal Pleistocene. However the intensification of cycad use was argued to occur from 4,300 years, at least in the south-central Queensland uplands (Lourandos 1997:143). Both Beaton and Lourandos drew links between the past use of Macrozamia in the CQH and ethnographic descriptions of aspects of hunter-gatherer economies, stating that the CQH evidence “may be an archaeological expression of emerging patterns of important Aboriginal social interactions that were widespread at the time of European contact” (Lourandos 1983a:90).

While the discipline has largely moved on from the specific debates surrounding the intensification model, the underlying concern with mid to late Holocene change, and its relationship with social or demographic processes has remained an important point of reference for many researchers. The idea that social and economic changes occurred across the continent has been taken up by a number of other researchers (Barker 1991, 1996; David 1994; Veitch 1996, 1999). Researchers commonly see changes in a small region to reflect wider continental scale processes, even if there is disagreement about the cause and nature of these changes.
Chapter 3: Sediment Taphonomy and Analysis

Archaeologists have become keenly aware that an understanding of the human past cannot be undertaken with an exclusive emphasis on artefacts in shoe boxes detached from both their physical context and behavioural matrix (Hassan 1987:1)

Introduction

The sediment matrices of the three archaeological sites have had a complex history, the analysis of which provides information concerning the formation of sites, and areas within sites. Knowledge of site formation processes allows a detailed consideration of the contextual associations of sediment and artefacts, providing information on depositional environments and history, post-depositional changes, and duration, continuity and rate of site formation. A comprehensive understanding of sediment formation processes has been developed since the 1970s (see Barham and Macphail 1995; Collison and Thompson 1989; Gerrard 1981; Gladfelter 1981:344; Halliday 1992; Hansen 2001:402; Hanson 1980; Hassan 1978:201-209; Hughes and Lampert 1977, 1980; Shackley 1972, 1974, 1978; Stein 1987:338-9; Stafford 1995:69; Sullivan 1984; Summerfield 1991; Turnbaugh 1978; Wood and Johnston 1978:316)

The three Central Queensland Highland (CQH) archaeological sites are located within a highly dynamic geomorphic environment. The sediment from the three CQH archaeological sites was analysed to investigate the depositional history of the sedimentary layers and reconstruct aspects of site formation. The sedimentary history of the three sites had not been adequately characterised prior to this analysis. This chapter follows the approach of Gifford (1981) in identifying the relevant taphonomic processes occurring in the archaeological sites of the CQH before beginning taphonomic analysis. The first half of the chapter discusses the major processes that shaped the sedimentological history of the sites in the CQH. The taphonomic processes of interest were 1) weathering processes of the sediments in the region, 2) source and mode of deposition of the sediments in the three archaeological sites, particularly fluvial deposition in Cathedral Cave, 3) bioturbation effects, 4) sediment pH, and 5) burial processes affecting the sediments in the sites, including compaction, overburden weight and pedogenesis. The second half of the chapter details the methods used to analyse the sediments and stratigraphy from these sites. The context and limitations of Beaton’s (1977, 1991a, 1991b) sediment analysis are also discussed.
Sedimentary Processes in the CQH

The majority of shelters and caves in the CQH have formed rapidly and relatively recently (c. 4,000 years) as a result of physical (wind, water) and chemical weathering of soft and friable Precipice sandstone (Beetson and Gray 1993:26; Davies 1979:10; Walsh 1999:39; Webb 1992:47). It is important to understand the sources and depositional contexts of the particles in rockshelters in order to reconstruct processes of site formation.

Source Area of Sediments

There are several sources of sediment available within the region where the CQH archaeological sites are located. The entire range of sediment sources in the region must be considered because the composition of the sediments in an archaeological site is a reflection of the geology of the source area and the particles available from the local environment (Pettijohn et al. 1987; Tucker 1982:20-21; Webb 1992). The major sources of sediments were identified through reference to geological maps to identify the range of parent lithology and mineralogy, analysis of the landscape topography and site setting (including drainage areas and hill slope processes) (see Table A-2 in the appendices for details) (Webb 1992:47). In the CQH, the major sources of sediment in archaeological sites were: 1) particles deposited from the weathering of the five major sandstone groups and basalt capping, and 2) minor particle deposition from wind, rain, slopewash and colluviation.

Depositional Processes

Sediments are transported and deposited and ultimately become trapped within archaeological sites by a number of different mechanisms over long time scales (Folk 1974; Reineck and Singh 1986; Stein 1987:340, 357, 1992; Webb 1992:47). Common processes of particle deposition in rockshelter sites include wind, water, gravity, biological organisms and humans (Hassan 1978, 1987; Stein 1987:366). In the CQH, the major depositional processes are 1) weathering exfoliation of individual grains from parent material at Rainbow Cave and Wanderer’s Cave, 2) mass wasting of sandstone blocks at Cathedral Cave and Rainbow Cave, and 3) fluvial deposition at Cathedral Cave.
Cavernous Weathering Processes

In Rainbow and Wanderer’s Caves the composition of the sediments are a reflection of cavernous weathering processes. Here, particles from the parent rockshelter have weathered and have become integrated into the matrix of the rockshelter deposit. Two types of weathering processes routinely act on parent shelter material: physical and chemical.

In the CQH, physical weathering has involved the disintegration of rocks and sandstones into smaller fragments as a result of alterations in climate. The main climatic processes include rain, wind, temperature, moisture and humidity. These processes cause diurnal expansion and contraction of the rock surface, water absorption and thermal fracturing due to fire (Costa and Baker 1981:146; Hassan 1978, 1987; Keeley and Macphail 1986:225; Wray 1997; Young and Young 1992). Chemical weathering disrupts the rock fabric, altering the mineralogical composition of the sandstones through reactions with water, oxygen and carbon dioxide. Sandstones in the CQH region weather relatively quickly because both kinds of processes are actively involved in sandstone weathering. The region has high rainfall, extremes of temperature and generally acidic soils (Chamley 1990:2; Costa and Baker 1981). The mean annual precipitation for the CQH of c. 1,000 mm (Walsh 1999:2), lies at the end of the range (250 mm -1,000 mm per/annum) considered to produce the highest rates of mechanical weathering in sandstone systems (Beetson and Gray 1993:19, 27; Chamley 1990:2; Costa and Baker 1981; Quinnell 1975:2) (Figure 3-1). The weathering is also fast because the sandstones are permeable, with poor grain matrix cement, meaning they are not very resistant to erosion (Costa and Baker 1981:120-127, 133; Walderhaug 1998, Appendix Table A-2).

Sandstone can also be deposited in archaeological sites as a result of mass wasting. All of the three sites have evidence that large and small blocks of sandstone have fallen from above the sites (Beaton 1991b:38; Walsh 1984:133, see Figure 3-1). The large scale mass weathering of rock fragments in the CQH is related to joints in the sandstone, with major joints oriented NW and SE, and weaker joints oriented NS and NE/SW (Beetson and Gray 1993, Figure 3-2). Erosion has also proceeded in a largely horizontal direction across bedding planes. The age of these rockfalls is difficult to assess given the very rapid rates of weathering, smoothing by animal activity and age staining of exposed surfaces. Studies of rockfall frequency in the CQH indicate that 5% of sites experience a rockfall every 10 years (Walsh 1984). Earth tremors are also thought to have been a significant contributing factor to the rockfall occurrence in the region. Anecdotal reports suggest that such events occurred...
at a number of sites in a localised region of the highlands at the same time (Mulvaney and Joyce 1965; Walsh 1984:134).

**Fluvial Deposition**

Evidence suggests that fluvial processes have been responsible for the deposition of the majority of the sediment in Cathedral Cave. Archaeological deposits interspersed with sediments deposited from flooding are relatively common (Overseas: Baker et al. 1983b; Baker et al. 1987; Benito et al. 2002:9; Crozier 1984; Partridge and Baker 1987; Patton and Boison 1986; Patton and Dibble 1982; Putnam 1994; Waters 1988; Australia: Dortch and Roberts 1996:28; Mulvaney 1959, 1960, 1987; Smith 1977; Williams 1982; Wyrwoll 1988). Beaton identified flooding to be a factor involved in the site formation of Cathedral Cave; however he was unable to resolve the timing, number, or impact of these flood events on the archaeological deposits.

The repeated nature of fluvial events recorded in this cave is not surprising when the particular geographic and climatological characteristics of the CQH region are considered. No other part of Queensland records more pronounced positive anomalies in rainfall variability, and considerable departures from the long-term averages are experienced where a summer of extreme drought may be followed by one of excessive floods (Bell et al. 1989:449; CSIRO 1965; Dick 1964:24). The region receives 80% of its annual rainfall during the summer flood season from September to December, which is directly related to the incidence of cyclones, thunderstorms, troughs and other rain depressions (Bell et al. 1989:449; Douglas 1977:99, 107). Cyclones affect the region on average once every 10-20 years, and the entire region is usually affected by extensive flooding accompanying the decaying cyclone. The CQH are positioned within an extensive, integrated drainage system of fluvial landforms (Douglas 1977:100; Pickup 1986:148; Walsh 1999). The sandstones in the region absorb most surface waters, except for periods of prolonged heavy rain, which results in heavy runoff, directed by gorge systems (Marshall 1995). Less severe floods occur outside the summer period; however streams are usually flood free and are at their lowest level between winter and early spring (CSIRO 1965:18).

Modern waterflow data from Wyseby and Rewan gauging stations nearest to Carnarvon Creek indicate that modern floods have high runoff rates and are capable of generating floods of up to four times the mean annual flow (Queensland Government 2003a; see also Eastgate et al. 1979). Figure 3-3 illustrates the dramatic variations in peak flow volumes for
Carnarvon Creek. Over the period from 1966 (when records start) to 1992, the mean annual total was 47,313 Mgl and the median flow was 31,636 Mgl (Queensland Government 2003b, Appendix Table A-1).

Extreme flood events in the CQH are not confined to the historic period. Current evidence suggests that flooding has been an important taphonomic factor in the CQH over the last 4,000 years. The climatic conditions of the early to mid Holocene are recorded in high magnitude floods at or very close to the maximum catchment limits in several areas of the Australian mainland (Hayne et al. 2001:218; Nott and Price 1999:275; Wohl et al. 1994). These dynamic geomorphic conditions and extreme climatic events appear to have a mid Holocene antiquity in the CQH region as indicated by a recent palynological study (Bell et al. 1989). Bell et al. (1989) analysed peat deposits and floodplain sediments of the Nogoa River, just inside the Carnarvon National Park designation, to the west of Cathedral Cave. They identified that minor climatic shifts have had a substantial environmental impact leading to alternating conditions of scour and fill of valley sediments in the region (Bell et al. 1989:449). A “severe” flood was identified in floodplain sediments of the Nogoa at 3,550 ± 70 years BP and a sample from a buried tree stump returned an age determination of 1,080 ± 60 years BP (Bell et al. 1989:455). Bell et al. (1986) suggest that the earlier part of the Holocene (pre 4,000 years BP) had a less variable climate than that of the present. They suggest that repeated erosional stripping and redeposition of alluvium by extreme climatic events are a feature of this area, occurring approximately every 500 years (between 1,000 BP to the present) (Bell et al. 1989:455; Finlayson and Brizga 1995:184).

Sedimentation Rate

Anecdotal reports suggest that an “alarming” rate of surface exfoliation of the precipice sandstones has occurred in the region over the last 140 years damaging art panels to 50% of sites and building up surface deposits (Walsh 1984). Sedimentation rates were established for sites and levels of sites by an extensive dating programme and assessment of soil formation stage. The rate of sedimentation in individual facies or archaeological deposits as a whole can be slow or rapid, and can have important taphonomic effects on archaeological materials. Long periods of sediment formation increase the susceptibility of sediments to taphonomic processes of reworking and alteration. The time estimated in these sediment build up rates is the sum of many episodes of sediment deposition and removal, including periods of deposition, physical and biological reworking of the sediments, periods of non-deposition and final burial and preservation of the bed (Brandt 1989:305).
Acidity

Significant differences in the measures of sediment alkalinity or acidity are likely to differentially alter the preservation of archaeological components, especially organics. This analysis uses the pH determinations obtained by Beaton at the time of excavation. Beaton took one sample from each level of Rainbow and Wanderer’s Caves; however no determinations are available for Cathedral Cave. These determinations are considered as a guide to pH in the levels of these sites. This is because a pH value taken from one part of a deposit (usually at the end of excavation after the sediments have been exposed to local area changes in moisture, heat and temperature) may not necessarily an accurate measure of the chemical and biological conditions in the rest of the deposit (Bowder 1983; Hughes 1980; Linse 1992:341; Matthiesen 2004). It remains likely that pH varied significantly at Cathedral Cave over the 70 m by 30 m area of the deposit, and that pH values may have changed at various times due to moisture influx as a result of repeated flooding events, as pH changes with the degree of dilution by water (Hughes 1983:114).

Post Depositional Processes

Bioturbation

Humans and animals are important taphonomic actors during the formation of a deposit (Stein 1987:340, 357, 1993; Webb 1992:47). Bioturbation processes can further alter the structure and appearance of humanly and fluvially deposited sediments. These agents have acted to disaggregate soils and sediments through churning, mixing, and trampling, and increase sediment porosity and potential for incorporation of non-cultural materials into sediments (scats, stored food, soils) (Behrensmeyer et al. 1989; Courty et al. 1989:140; Johnston 2002; Lyman 1994; Matthews 1965; Reineck and Singh 1986).

Human Disturbance

People are often significant agents of site formation and transformation (Schiffer 1972, 1976, 1987; Solomon 1985). Anthropogenic alterations to deposits in the region have been extensive over the last century and have affected the upper levels of sedimentary deposits of the CQH. Visitation commenced from the late 1800s. Avoidance of the draft in World War I led to men hiding in the CQH from 1914-1918 (Walsh 1999). During the 1920s and 1930s, many people came to the area to cull native animals. The 1930s and 1940s saw several fact
finding and exploration expeditions undertaken in the region, the main means of access to
the region was by horse and donkey (Beaton 1977; Davies 1979:8; Walsh 1999, see also
Brammall 1940; Goddard 1941-2; O’Brien 1941-2) (Figure 3-4). The 1950s and the 1960s
saw an increase in visitation from family groups, aided by the advent of the four-wheel drive
and tourism campaigns. Army exercises were held in the rugged region in the mid-1960s,
and camping was allowed in the shelters of the National Park until 1974 (Davies 1979;
Walsh 1999). Early and extensive visitation and human disturbance to the archaeological
sites in the region is supported by studies on the occurrence, timing and extent of vandalism
of art sites throughout the highlands, including the more inaccessible areas (Godwin et al.
Cave is indicated by rubbish excavated from several areas in the upper level of the deposit
by Beaton. Previous excavations in Cathedral Cave are also likely to have affected at least
the upper stratum (Figure 3-5). Visitation to Cathedral Cave, located in one of the most
visited gorges of the CQH, is discussed specifically in Chapter 8.

Animal Disturbance

The archaeological deposits in the CQH may also have been subjected to disturbance from
large to medium sized animals including cattle, wallabies and dogs. Cattle were considered
to be a significant factor as the CQH was established as a cattle run from 1863 to 1932
(Davies 1979:2; Walsh 1999). Cattle walked over archaeological sites and rubbed against the
sandstone walls of several art sites in the region (Walsh 1999). Cattle can cause the vertical
and horizontal displacement of artefacts and disturb stratigraphy with their hooves (Lyman
1994). Several species of Macropods also inhabit the gorge and are known for resting in
caves and rockshelters producing “wallaby slumps”, depressed hollows on the surface of
deposits. Domestic and wild dogs were often in the CQH and are also known for causing
stratigraphic disturbance through digging deposits, denning behaviour and adding organic
material to the deposits. Beaton did not identify evidence of these taphonomic processes at
the time of excavation.

A range of small animals and organisms were also considered as potential agents of
bioturbation in the CQH sites. Several studies indicate rodents, earthworms, ants, termites,
ants, spiders and other insects add or remove organic material and alter the chemistry of the
soil by creating channels for water percolation and aeration of the deposit (Auld and
Denham 1999; Bocek 1986:591, 601; Canti 2003; Courty et al. 1989:142; Dolva and Scott
1982; Erlandson and Rockwell 1987:54-57; Fowler et al. 2004; Martinez et al. 2004,
Pettijohn 1987:98-104; Stein 1983:281; Tucker 1982:74-87; Wood and Johnston 1978:325). Although these agents were possible in the CQH, no evidence was found at the time of excavation. Photographs of the stratigraphic profiles, and stratigraphic diagrams and notes were analysed for evidence of rodent burrows or earthworm burrows, casts, burying finds, cairns or granular layers (Canti 2003; Fowler et al. 2004). These were not identified. Other processes including agrilliturbation, soil creep and floralturbation (Erlandson and Rockwell 1987; Wood and Johnston 1978:329) could not be further assessed beyond Beatons’ (1977, 1991a, 1991b) original interpretation of site disturbance.

The region is also home to several different species of insects and beetles, which burrow into sediments during part of their life cycle (Lawrence and Britton 1994; Matthews 1984; Smith 2000; Tyndale-Biscoe 1990). Several deep longitudinal “beetle” burrows were identified at the time of excavation of the Cathedral Cave deposit (Beaton 1977, 1991b). The insects creating these features have been identified in this study as belonging to the family Carabidae and Scarabaeidae (Hawkeswood 1987; Zborowski and Storey 1965). These species excavate earth burrows and longitudinal chambers in which to breed (Elias 1986, 1996; Hawkeswood 1987; Jones 1987). Although they are usually considered to be soil transformation and taphonomic factors in archaeological sites (Chamley 1990:83; Stein 1983; Wood and Johnston 1978), the burrows in Cathedral Cave were confined to strata emplaced by fluvial events.

**Compaction**

Beaton subjectively assessed the compaction of the sediments of the CQH sites, and at Cathedral Cave applied bulk density tests to assess compaction (Beaton 1977, 1991a, 1991b). Compaction increases the bulk density of the sediments, and can compress depositional events and objects within strata. Bulk density tests are an index of the composition and packing of the material and give a feel for the relative compactness of substrates and diagenesis (Gordon et al. 1992:210). As the volume of voids between the particles increases, the bulk density decreases. Compaction was considered to be a significant factor at Cathedral Cave where a deep (5 m) deposit extended over an area of 70 m by 30 m, especially with the added weight of water. At Cathedral Cave the 14 stratigraphic layers vary in depth, extent and compaction. The relatively shallow (<50 cm) deposits at Rainbow and Wanderer’s Caves were not expected to have significant sedimentary alterations.
Sediment Taphonomy: Analytic Methods

Sampling Issues at Rainbow and Wanderer’s Caves

At Rainbow and Wanderer’s Caves Beaton collected and bagged sediment from one wall of one excavation pit in arbitrary 5 cm units. This results in the aggregation of deposits, limiting us to coarse grained interpretations of depositional history (Behrensmeyer and Chapman 1993). The depth and consistency of deposits were also tested but no samples were taken in these other areas.

Sampling Issues at Cathedral Cave

At Cathedral Cave, Beaton collected sediments using a “column sampler” placed in the middle of each of the stratigraphic units defined at the time of excavation. There are two main problems that arise from the different method of collecting sedimentary samples at Cathedral Cave which mean that the deposit may not be adequately characterised for a fine grained reconstruction of depositional processes.

The first problem is the location of the sediment column sample. Although nine pits were excavated in the site, only one pit was used for sediment sampling. Beaton believed that different areas of the site were formed under different histories of deposition, and created different stratigraphic profiles for each pit in the site. However variations in the depositional processes in different areas of the site are unable to be investigated because of the lack of sediment samples from other portions of the deposit. Sampling other parts of the deposit that exhibited changes in sedimentary characteristics can provide important information concerning depositional history (Folk 1974). While Beaton did appear to collect specific information concerning some layers at the site which suggest a complicated depositional history, the size of the samples were too small to provide adequate samples for sediment analysis, and they were placed at too large an interval to adequately characterise the sedimentary profile (Folk 1974).

The second problem concerns the sampling of sediment in each depositional layer of the unit. Although Beaton designated 14 sedimentary levels in the site, he also noted several changes in the sizes of sediments within these designated levels, however these were not sampled. Samples were taken from the middle of some levels, and from the top, middle and bottom of other levels (Beaton fieldnotes 1975). This sampling technique meant that each level was only partially sampled, and were inadequately characterised. Thus, important
information concerning natural and human site formation processes was not obtained (Courty et al. 1989:42; Lennstrom and Hastorf 1992:206, 225-226; see also Bates et al. 2000 and Thorson 1996 for excavation strategies in alluvial sediments).

Even with these limitations however, a model of fluvial deposition at Cathedral Cave was able to be constructed and the potential effects on cultural material at the site were able to be assessed (see below, and Chapter 8). A number of analytic techniques are used in geomorphology to understand fluvially emplaced sedimentary deposits (discussed below). The sampling strategy Beaton used precludes a fine grained interpretation of the stratigraphy of the site. For example, the fluvial events in some levels are more clearly understood than those in other levels, the exact number of flood events in some levels are not known, and in some levels clear stratigraphic and grain size data are lacking, preventing the definition of the beginning and the end of the fluvial deposition events. The fluvial model constructed here can be refined with further research.

Sample Preparation

An analysis of the grain sizes in an archaeological deposit provides information concerning the source of sediments. In geomorphological analysis, sediments are generally divided into three main categories: sand, silt and clay (Folk 1974; Hassan 1978; Pettijohn et al. 1987; Reineck and Singh 1986; Stein 1987; Webb 1992). The size of these grains and their mineralogy are used to determine the source of the sediment (Hughes 1980, 1983). The phi scale demarcates the different clast size categories (Table 3-1, Table 3-2).

The sedimentary fill in rockshelter deposits can be deposited from a number of sources as a result of a variety of mechanisms. Grain size parameters can also be used as a measure of the energy of the transport medium. In most rockshelter sites the sedimentary fill is made up of coarse, medium and fine fractions. The coarse fraction (granules, very coarse and coarse sands) are derived largely from products of parent material breakdown. However high energy processes including some fluvial processes, mass movements and human activity may also contribute this fraction (Hassan 1978:202-3; Pettijohn et al. 1987; Reineck and Singh 1986; Stein 1987:358; Webb 1992; Woodward and Goldberg 2001; Woodward et al. 2001:502). The fine sediment fraction in a rockshelter (medium and fine sands, silts and clays) are usually deposited in lower energy processes by aeolian and some kinds of fluvial processes (Hassan 1978:202-3; Knighton 1984; Pettijohn et al. 1987; Reineck and Singh 1986; Stein 1987:358; Woodward et al. 2001:502). However the size of grains available in
the source area must always be considered (Stein 1987:358) as in most environments, grain sizes reflect the depositional energy in the environment (Tucker 1982:37).

The sediment samples obtained by Beaton were used in this analysis. The identification of the sedimentary processes in the sites was derived through analysis of the grain sizes of the sediments and their distribution in the sedimentary profile (Pettijohn et al. 1987; Shackley 1972:133, 1974). While the grain size of particles over several centimetres was measured with callipers, the majority of the sediments were smaller and required mechanical sieving to determine the grain size distribution (Lindholm 1987:157). Sediment obtained from Beaton’s original bags containing column samples was opened and the sediment shaken to separate aggregations of grains produced by transport and storage conditions. A 100 g sub-sample was collected from each larger bag of sediment, and spread out thinly on trays and allowed to dry at room temperature, and any remaining aggregates were broken up by hand so as not to fragment the particles (Gordon et al. 1992:201).

**Methods of Analysis**

The total weight of each sample of sediment from each layer was weighed to four decimal places (g) prior to analysis. The sediment was then placed in the top of a series of 11 nested Endicott sieves, arranged in order so that the coarsest sieve was at the top and the finest sieves below, with a pan at the bottom to catch sediment that passed through the lowermost sieve (Lindholm 1987:157). A regular interval of a half phi was used. Sedimentologists use the (Wentworth) phi scale where phi is equal to the negative logarithm (base 2) of the particle size in millimetres (each grade limit is twice as large as the next smaller grade unit) (Folk 1974:23; Gordon et al. 1992:194). The nest of sieves was then placed on the Durolab mechanical shaker with a lid fastened tightly on the top. All samples were mechanically shaken for 20 minutes. The sieving procedure separates the sediment into different size classes according to the diameter of the sieve openings (Hassan 1978:205; Lindholm 1987:157; Stein 1987:357). The sediments were removed from the shaker, following standard sedimentological procedures (outlined in Folk 1974:32; Gordon et al. 1992; Hassan 1978:205; Lindholm 1987:158; McManus 1988:66-68). The sediment remaining on each sieve was weighed to four decimal places (g). The sample was then also examined under an x10 hand lens for analysis of mineral inclusions, microdebitage and organic matter (Folk 1974; McManus 1988:66).
Interpreting Grain Size Data

The sediment grain size data provides information on the relative distribution of sand, silt, clay and gravel in an assemblage. The grain size data are then subjected to a range of statistical measures. The grain size distributions are presented graphically using histograms with the percentage by weight of each size grade are plotted (Lindholm 1987:163). Histograms of sediments can be unimodal, displaying a prominent size class (modal class), however histograms of sediments can also be bimodal or polymodal where more than one mode is displayed (Lindholm 1987:165; Doeglas 1946; Shackley 1972, 1974, 1978).

Statistical parameters of grain size are also presented to better describe features of the curves. The basic measure involves plotting the cumulative curve of the sample and reading the diameter presented at the 5%, 25%, 50%, 85% and 95% marks of the sediment curve. This allows the central tendency to be characterised by specifying the mean, median and modal sizes of the sediment, and also permits consideration of the form of sediment distribution by shape, sorting and skewness of the sediments in the sample (Folk 1974; Shackley 1972:133). All three measures of central tendency reflect the average kinetic energy of the depositing medium plus the size distribution of the available sediment (Pettijohn et al. 1987:74). The median and mode can be analysed to understand the homogeneity of the distribution of sediment types and sizes (sorting). Taken together these measures indicate the depositional history of the site matrix and allow ease of sample description and comparison of environmental, spatial and stratigraphic differences between samples and sites (Lindholm 1987; McManus 1988; Pettijohn et al. 1987; Shackley 1972:138; Vischer 1969).

Analysis of the modal grain size provides information on sediment transport. The modal grain sizes and their consistency can indicate if several sources and depositional processes are operating in the site. The mode (Mo), the most frequently occurring particle size, corresponds to the steepest point on the frequency curve. The median (Md) is derived by identifying the grain size (φ) at the 50% mark on the cumulative curve and is that size for which half the particles (by weight) are coarser and finer, expressed as phi or in mm (Folk 1974; Lindholm 1987:166; McManus 1988). The mean (M) is the best measure of average grain size, and computed from sizes of particles spread through a range of percentile values, and in its simplest form can be computed from the graphic mean (McManus 1988:77). The graphic mean (Mₗ, of folk) is a function of the range of available materials and the amount of energy imparted to the sediment and transport conditions (e.g., velocity and turbulence). The
mean size of sediments can be determined by the formula $M_z (\phi 16 + \phi 50 + \phi 84)/3$ (Folk 1974). For most samples the median, mode and mean are clustered near the high point of the frequency curve (Lindholm 1987:167).

Sorting measures the dispersion of the sediment, and as it is dependent on velocity of the depositional processes, can provide information concerning fluctuations in the deposition of the sediment (Pettijohn et al. 1987:74). Measures of uniformity and sorting ($\sigma$) of particle sizes around the average grain size of the sediments, can also be identified using the standard deviation (SD) of the sediment. The more of the curve that enters into the sorting co-efficient, the more accurate the measure, some measures taking the central 2/3rds of the curve, with others considering the tails (see Folk 1974:43; Hughes 1983:115; see also McManus 1988:77 for various methods). The three measures used in this analysis are the Graphic Standard Deviation ($\sigma_{G}$) of Folk ($(\phi 84 - \phi 16)/2$) which considers the central 68% of the distribution; the Inclusive Graphic Standard Deviation ($\sigma_{I}$) of Folk 1974: $(\phi 84 - \phi 16/4) + (\phi 95 - \phi 5 / 6.6)$, which includes 90% of the distribution and is the best overall measure of sorting; and measures of skewness or asymmetry, which were derived from grain size data. Graphic skewness ($Sk_{G} = (\phi 16 + \phi 84 - 2 \phi 50) / (\phi 84 - \phi 16)$) measures the displacement of the median from the average of the $\phi 16$ and $\phi 84$ points and is geometrically independent of sorting. The descriptions of sorting and skewness are outlined in Table 3-2 (Folk 1974:42; Lindholm 1987:171; McManus 1988:78).

**Particle Mineralogy**

Physical and chemical weathering produces three main types of product common in archaeological sites of the CQH. The analysis of the mineralogical suites of the grain sizes in the sedimentary deposit can be used to cross check the sources and mode of sediment deposition. These products include large and small fragments of rock (basalt, granites, and schist), mineral grains of rock (including quartz, feldspar, mica, and muscovite) and secondary materials (clays) and soluble chemicals (ions and oxides) (Costa and Baker 1981:146; Hassan 1978:1987). In this analysis the minerals in the sand fraction (2.0 - 1.0 $\phi$) of the grain sizes were compared to the range of minerals in the parent lithology, and other sediments characterised in the region (Beeton and Gray 1993; Mulvaney and Joyce 1965).
Methods of Palaeoflood Analysis at Cathedral Cave

Establishing the source of sediments and potential depositional processes in rockshelters is essential to understand site formation processes. Repeated fluvial events were a significant factor in the formation of Cathedral Cave. Therefore, it was necessary to understand the condition under which these sediments were deposited, the nature of the flood events and effects on archaeological materials deposited within the site. Significant advances in fluvial geomorphology and interpretations of palaeoflood hydrology have occurred since the time of Beaton’s excavation in 1975. Extensive literature reviews of fluvial geomorphology and methods commonly used to analyse fluvial sediments were undertaken to define a range of methods to interpret the fluvial history of Cathedral Cave. These included ascertaining the site chronology, analysing stratigraphic descriptions and drawings, collating photographic evidence, performing sedimentological tests (grain size, mineralogy, as above), and understanding fluvial hydraulics to answer site formation issues. The main methods used were: 1) grain size analysis (as above), 2) understanding general processes of flooding, 3) analysis of environmental context of the site, and 4) stratigraphic analysis.

Analysis of Flood Aetiology

Research into palaeoflood hydrology by fluvial geomorphologists over the last 30 years has identified a diverse and unique set of fluvial depositional environments within sandstone gorge systems. After prolonged rain events, runoff from stream banks and streams from the catchment area, carries sediment from source areas (weathered debris and coarse to fine particles), through the drainage network to the main channel where sediments are deposited, forming several kinds of flood deposits. In peak flood flows, larger sediments are transported in the main channel and carried downstream until velocities drop, causing deposition. Smaller grain sizes are deposited in areas of quiet or “slack” water (called slackwater deposits, or SWD) away from the main channel, where fine grain sizes can settle out under quiet water conditions.

Slackwater deposits are a common type of flood deposit that occurs in gorge systems at areas distal to the main channel. Cathedral Cave is perfectly positioned to accumulate SWD’s as it is positioned in this environment. SWD’s consist of fine grained sand and silt that have settled out of suspension from sediment laden floodwaters during high stage flood events in zones of reduced flow velocity (separated flow areas) at marginal areas to the main channel (Benito et al. 2002; Ely 1997:177; Miall 1983; Woodward and Goldberg 2001; Woodward et al. 2001; Yang et al. 2000). During high flood stages, the main flood flow is
directed down the main channel of the river. In areas removed from flow in the main channel (e.g., channel margins, tributary mouths, rockshelters, on the lee side of channel obstructions and lee sides of talus obstructions and channel expansion or constriction) (Figure 3-6) flow is greatly reduced in comparison to the main channel. In these locations, flow separation, backflooding and water stagnation occur, creating slow moving, low velocity local flows, usually less than 1 m/s\(^1\) (metre per second; a derived unit of both speed (scalar) and velocity (vector), defined by distance in metres divided by time in seconds) (Baker 1987; Baker et al. 1979, 1983a, 1983b, 1985; Benito et al. 2002:1; Kochel and Baker 1982; Kochel et al. 1982:1165).

Such conditions favour the deposition from suspension of clay, silt and sand (Benito et al. 2002:4, 10; Springer and Kite 1997:93; Yang et al. 2000:81). These sediments are transported by the fluid and carried at the same speed as the water. Low velocities and minor turbulence are required to keep them in suspension, but they settle out quickly when velocities drop (Baker et al. 1983b; Gordon et al. 1992:293). SWD sediments are deposited beneath an intermediate, overlying depth of water and their accumulation is supply limited (Jones et al. 2001:49; Partridge and Baker 1987:115).

**Influence of Environmental Location**

Long term deposition of slackwater sediments can occur in areas marginal to the main channel (Benito et al. 2002). SWD only record high stage flood events, and if a flood fails to exceed the existing surface of a prior SWD, the most recent high stage flood will not be recorded in the series of SWD. Lesser stage floods may be recorded as an inset terrace, which can be rapidly re-worked by subsequent flood events (Kochel et al. 1982:1167). SWD can provide detailed records of flood events that can extend back thousands of years (Baker et al. 1983a:230; Ely 1997:177; Patton and Dibble 1982:108; Paton et al. 1979). The Arenosa shelter in Zixto Canyon has an extensive SWD formed over the last 10,000 years, interleaved with cultural deposits (Patton and Dibble 1982:108). SWD are also subject to alteration by post depositional processes including rainwater, weathering, trampling and biogenic processes (Baker et al. 1983a:238; Baker et al. 1987:83; Kochel et al. 1982:1165, 1170; Patton and Dibble 1982:108; Springer and Kite 1997:92).

As a result of fluvial geomorphological research into SWD it is now recognized that different types of SWD can occur in specific environmental locations (Baker et al. 1979; Baker et al. 1983a; Costa and Baker 1981; Ely 1997; Kale et al. 2000). Four different types
of SWD have been identified based on different depositional processes in four different depositional environments in high flow stages: channel widening, canyon expansion, bedrock obstacles, and backflooded areas along tributary channels (Benito et al. 2002, figure 5, reproduced here as Figure 2-7). A description of flood flow conditions that generate sediment deposition in these four main depositional environments is presented in Appendix Table A-5.

Stratigraphic Analysis

Variations in flow conditions in marginal canyon environments result in different stratigraphic characteristics for each of the four slackwater deposits (Table 3-3). Differences in bed type, size and internal characteristics occur due to differences in the depositional environment in specific areas of sandstone gorges. Different depositional environments are related to the environmental position of the sedimentary deposit in the gorge, local hydrology and flood stage (Benito et al. 2002; Pickup et al. 1988:148). These deposits can be differentiated by considering the environmental position of the sedimentary deposit in the canyon (e.g., tributary mouth) along with stratigraphic and sedimentary characteristics of the sedimentary deposit itself (Ely 1997). Common stratigraphic features have been identified for each type of SWD in different environmental locations (Benito et al. 2002). Specific combinations of specific stratigraphic features can be used to differentiate these deposits.

Variations in the characteristics of fluvially deposited beds are also common even within one site of slackwater deposition (Benito et al. 2002; Williams 1982). Stratigraphic layers (beds) can vary considerably in type, structure and thickness. Bed thickness can range from "massively thick" to extremely thin beds called "laminations". Several types of beds with their own internal characteristics can form at different parts of one slackwater depositional location as a result of local variations in flow stages. As a result, SWD record information about processes of deposition within beds. Individual beds formed under slackwater conditions may contain thick or thin structures indicating flow conditions and current information (trough cross bedding, convoluted bedding, ripple laminations, parallel laminations, graded bedding, mudcracks and mudclasts), and display features indicating downstream or upstream flow (eddies) (return climbing ripple laminae, return climbing ripple drift laminae, return small trough cross bedding). Different types of bedforms and their depositional processes are described in Table 3-3.
Rockshelters are common sites of SWD. Taking into account its environmental position within the gorge system, and its stratigraphic features, the Cathedral Cave sedimentary deposits are most consistent with slackwater tributary mouth SWD. Cathedral Cave is located marginal to the main river channel and within the middle reaches of the river, where large and small floods are often represented. The cave is also located near a tributary mouth, and has a tributary-main channel junction angle of 70-90° (measured from the tributary axis to the downstream segment of the mainstream axis). Tributary angles between 90 and 120° are optimal for the preservation of SWD. Higher junction angles limit the access of water to the tributary mouths and lower junction angles (5-60°) allow the main stream flow to erode SWD in high velocity flow (Kochel et al. 1982:1171). The cave is also positioned at a canyon widening point. The environmental position can be compared to other sites with SWD in tributary mouth environments as presented by Benito et al. (2002) and Kochel et al. (1982:1168). The stratigraphic features of Cathedral Cave are also consistent with tributary mouth SWD. The majority of the beds at Cathedral Cave were horizontally laminated units, with massive structureless units at the base of the deposit. Other features of the deposit include silt and mud layers, and possible mud cracks. The specific palaeoflood history of Cathedral Cave is discussed in detail in Chapter 8.
Chapter 4: Vertebrate Taphonomy and Methods

...caves and rockshelters are unusual depositional environments...this does not however mean that caves are the best places to recover faunal remains that have undergone minimal taphonomic modification (Lyman 1994:414).

Clearly, there is only one way to arrive at the conclusion that [Palaeolithic] and other faunas were collected and modified by none other than Homo sapiens, and that is to avoid the subject of taphonomy completely (Stiner 1994:95).

The caves in the CQH have been effective and efficient sediment traps while acting as a fixed focal point for human activity in the landscape. The caves have attracted a range of predatory and non-predatory animals who have served as bone accumulation and depositional agents, variously visiting, occupying, abandoning cave sites; and depositing, modifying and abandoning prey carcasses, and defecating the remains of meals (Auban et al. 2001; Hope 1978, 1980:44; Robles et al. 2002:145). Although Beaton noted that dingoes might have been a taphonomic agent, he also claimed that most of the remains were the result of human prey choices. However, none of the faunal remains from these sites had been assessed taphonomically. As a result, the faunal assemblages should be viewed as aggregated, selective representations of past actors and faunal suites, which have been further modified by several types of taphonomic events (Guilday et al. 1962; Hope 1980:44; Shipman 1981). Given this, careful analysis of the creation and modification of the faunal component in the CQH sites were warranted.

The range of taphonomic actors and processes involved in their transport, deposition and modification were identified through a review of taphonomic and archaeological literature from Australian and overseas contexts. This analysis considered 1) transport, deposition and accumulation by both humans, canids and floods, 2) modification of prey by both humans and canids, defining criteria through which to differentiate actors in the Australian context, 3) disturbance by plants, animals and humans, 4) post depositional processes including physical and chemical weathering, 5) overburden weight and compaction, 6) burial processes, 7) excavation and curation biases, and 8) analytic biases. The first half of the chapter provides a discussion of the general issues involved in taphonomic research in the Australian context. The second half of the chapter discusses the specific methods used in the analysis of the faunal specimens.
Depositional Processes

Identification of Predators in the Faunal Assemblage

A wide range of species inhabit the CQH and they each have a range of landscape preferences (Appendix Table A-8), and predator and prey relationships (Appendix Table A-11). These relationships were studied to accurately identify the accumulation and dispersal agents in the CQH sites. The main predators considered likely to have deposited and modified assemblages included 1) Australian hunter-gatherers (Basedow 1907; Spencer and Gillen 1889 [1968]), 2) owls (see Andrews 1990; Baird 1982; Dickman et al. 1991; Dodson and Wexlar 1979; Elandson and Moss 2001:421; Fernandez-Jalvo and Andrews 1992; Geering 1990; Kusner 1990:636, 633; Kavagnah 1996; Lundie-Jenkins 1996; Morton et al. 1977; Schultz 1997; Seebeck 1976; Tilley 1982; Worthy and Holdaway 1994), 3) eagles (Brooker and Ridpath 1980; Mayhew 1977), 4) dingoes (Lunney et al. 1990, 1996; Thomson 1992a, 1992b, 1992c, 1992d, 1992e; Webb 1994; Whitehouse 1977), and 5) foxes (Brunner et al. 1975, Brunner et al. 1976; Catling 1988; Croft and Hone 1978; Morrison 1981; Stallibrass 1984; Triggs et al. 1984). A literature review identified analytical correlates of the activities of each of these agents.

Only two major taphonomic agents were identified in the archaeofaunas of the CQH: the human and the dingo. The Australian situation mirrors several others overseas, in that the prey choices of humans and the wild and semi-commensal dog (C. lupus dingo) overlap (Caughley et al. 1980; Corbet 2001, Kohen 1995; Johnson and Wroe 2003; Newsome et al. 1983a, 1983b; Newsome and Coman 1999; Shepard 1981). This is particularly the case for wallabies and kangaroos (Petrogale sp. and Macropus sp.), which are relatively abundant in the CQH (Strahn 1983, 1995), and were hunted by both humans and dingoes. The present archaeological and ecological data concerning dingo behaviour suggest dingoes conduct some of their activities within caves, and that dingoes have been associated with human campsites since the mid Holocene (Corbett 2001; Gould 1979; Hamilton 1972; Hayden 1977; Megitt 1965; Solomon and David 1990:234; Walters 1984).

Humans and Canids

Processes of carnivore modification have affected faunal remains in archaeological sites around the world. The extent to which faunal assemblages represent human or animal
activity has been a major concern of zooarchaeologists and taphonomists. Several studies focus on the Hyaena (Hyaena sp. and Crocuta sp.) as an agent of bone accumulation, modification and attrition, especially in Africa, Asia and Europe (Binford 1981, Binford et al. 1988, Blumenschine 1986, 1987, 1988; Blumenschine and Marean 1993; Bunn 1983, 1989; Capaldo 1998, Hill 1989a, 1989b; Horwitz and Smith 1988; Lam 1992; Marean et al. 1992; Selvaggio 1998; Selvaggio and Wilder 2001; Stiner 1994; Sutcliffe 1970). However, analysts investigating modifications by non-hyaenid predators are unable to apply methods or interpretations obtained from these studies as the hyaena is not an appropriate interpretive analogue being several orders of magnitude more destructive on faunal assemblages than dogs (Marean et al. 1992:102; Wroe et al. 2004).

Overseas, studies on patterns of faunal modification by smaller carnivores with less powerful jaw strengths have also been conducted. These studies have included analysis of patterning in actualistic feeding experiments using dogs and wolves (Binford and Bertram 1977; Payne and Munson 1985; Simek and Snyder 1988; Solomon 1985), ethnoarchaeological studies analysing the effects of dogs on humanly caught prey (Binford 1978; Binford and Bertram 1977; Brain 1967; Hudson 1993; Walters 1984) and natural assemblages from wolf kill sites and dens (Binford 1981) are available.

Carnivores in Australia

Understanding the impact of carnivore actors is also important in the Australian context, as at various times over the last 40,000 years there have been six mammalian agents of faunal transformation active in and around archaeological sites. The Tasmanian wolf (Thylacinus cynocephalus) was a large carnivorous solitary or paired hunting mammal with long powerful jaws, which was widespread on the continent and Tasmania. The wolf hunted kangaroos, marsupials, small rodents and birds before becoming extinct on the mainland c.3,100 BP (Dixon 1989; Corbett 2001:139). The Marsupial Lion (Thylacoleo carnifex), was a scavenger and hunter of mainland faunas prior to 10,000 BP (Archer 1974b, 1974c; Solomon and David 1990). The Tasmanian devil (Sarcophilus harissii), a scavenger of small prey, only became extinct relatively recently on the mainland c. 430 BP (Archer and Baynes 1972; Johnson and Wroe 2003; Marshall and Cosgrove 1990; Walshe 1993). The dingo (C. lupus dingo), a carnivorous scavenger and hunter of small to large prey, has operated throughout the Australian continent at least from c. 3,450 BP (Corbett 2001; Lilham and Thomson 1976; Newsome et al. 1983a). Quolls (Dasurus sp.), small carrion scavenging animals, were also common throughout the continent (Corbett 2001; Gollan 1984; Johnson
and Wroe 2003:1009; Lundelius Jn 1966; Solomon and David 1990), while the European introduced Fox (Vulpes vulpes) has also been a major hunter of small and medium prey (Stallibrass 1984). In all time periods, these carnivores preyed upon animals and scavenged upon carcasses, affecting the way carcasses were utilised, disarticulated, dispersed and modified (Reed 2001:629).

Australian archaeologists have recognized the extent to which canids may have contributed to the formation of faunal assemblages within Australian archaeological sites over the last 3,500 years (Solomon and David 1990; Walters 1980), both as the companion dogs of humans, and as independent taphonomic actors (Johnson and Wroe 2003:1010). Some archaeologists argue that canid signatures are the dominant biological overprint on the majority of Australian faunal assemblages (Solomon 1985; Walshe 1994a, 1994b, 1999, 2000). To investigate the extent of canid modification in Australia, correlates of both human and dingo modifications of Macropod prey carcasses have been generated from small scale experimental studies (Solomon 1985; Solomon and David 1990). This prior research is important as it provides baseline data for the identification of canid modification of faunal assemblages in the Australian context. However, correlates have largely focussed on identification of dingo traces on faunal specimens. Ecological data suggest a wealth of information concerning dingo behaviours that may also be developed into correlates which can be tested against the archaeological record.

**Investigating Correlates of Canid and Human Association with CQH Prey Faunas**

Overseas investigations of archaeological correlates of canid modification of faunal elements have focussed on two principle lines of evidence: differential species representation and differential element representation (Behrensmeyer 1987, 1993; Stiner 1990, 1991, 1994, 2002). Commonly applied analytic tests investigate 1) prey age, 2) prey size, 3) species selectivity, 4) differential representation of body regions, 5) differential representation of elements within body regions, and 6) differential representation of regions within elements. However the particular correlates developed in overseas contexts, while useful indicators of canid activity, cannot be directly applied to the Australian context due to differences in available prey species, prey size and skeletal morphology, and predator jaw strength. The following section uses a range of Australian data (ecological, anthropological, experimental and archaeological) through which to investigate possible correlates for the identification and differentiation of human and canid actors in the CQH assemblages.
Prey Size and Species

Unusual frequencies of particular species or animal body sizes in archaeological sites have been used as indirect evidence of selective predation by both human or canid carnivores. Canids in particular are thought to produce assemblages of highly selective (non-random) species representations due to limitations of body size and strength. If the species represented in archaeofaunas match the extant prey selection, then this data is used to identify the persistent activity of a particular carnivore (Behrensmeyer 1993; Kowalewski 2002:21).

However in the Australian case, it is not always easy to differentiate prey selection by dogs and humans based on animal size alone. Australian fauna range from 300 g to more than 80 kg and ethnographic, anthropological and archaeological evidence suggests that most of these species were the prey of humans. In the Holocene, the largest humanly hunted indigenous mammalian fauna were the large kangaroos, the largest males of which could weigh 90 kg (Menkhorst and Knight 2001; Strahn 1995). Ethnographic records suggest that humans were opportunistic hunters, taking small, medium and large animals, while concentrating efforts on the medium to large Macropods.

The available ecological data also suggests that canids can easily catch animals of all size groups, either individually, or in packs using a fluid social structure and a broad range of hunting strategies (Corbett 2001:102; Wroe et al. 2004). Studies into dingo diet in all environmental types in Australia have identified 177 prey species. Almost 75% of these were mammals, comprised of 18% birds (53 species), 1.8% reptiles (23 species) and 3.8% comprised of insects, crabs, and frogs (28 species) (Corbett 2001:102). The relative proportions of mammals, birds, reptiles and other prey that dingoes eat is very similar throughout Australia, with the exception that more reptiles are eaten in central Australia (see also Walters 1984) and more birds are eaten in the northern and southern coastal regions (Corbett 2001:102). Of the mammals, 80% were small to medium sized, as this body size is most common in Australia, while about 20% were larger sized animals (Corbett 2001:102). However, almost 80% of the diet in all regions comprised only 10 species. This suggests that the dingo is a specialist on main prey species, and a generalist over the entire range of prey species taken (Corbett 2001:107). Corbett and Newsome (1975a, 1975b:378) suggest that prior to European occupation, the prey of solitary dingoes would have consisted mainly of small to medium sized animals, including possums, bandicoots, rat kangaroos and wallabies and kangaroos. These prey types comprise a major part of the dingo diet in the CQH today (Corbett 2001; Robertshaw and Harden 1985; Whitehouse 1977) (Table 4-1).
The complex social organisation of dingoes allows them to switch between solitary hunting of medium sized prey to group hunting for larger sized prey. Dingoes usually hunt alone when single small to medium sized prey are available, attacking prey from ambush or by chasing (Hume et al. 1989:42; Newsome and Coman 1999; Pople et al. 2000:269). Tactics for the capture of small and medium prey (up to 20 kg) are similar to those used for large kangaroos, with a high success rate for single dogs hunting medium sized Macropods (Corbett 2001:115). When large game is available and small game are absent, dingoes hunt co-operatively in integrated packs of between three to 12 dogs, to maximise hunting success (Corbett 2001:6; Pople et al. 2000:269). Throughout Australia, various species of large kangaroos (between 17-70 kg) are the most common large prey killed by packs (Shepherd 1981). Packs of dingoes are more than three times more successful at bailing up kangaroos and more than two times as successful at killing them in packs than if they hunted by individual dogs (Corbett 2001:115). Reports of co-operative hunting involving large kangaroos and horses, and the defence of carcasses and water resources are also common (Corbett 2001; Johnson and Wroe 2003:1010; Newsome et al. 1983a, 1983b; Newsome et al. 1999).

Age Spectra

Comparing the age spectra of the archaeological sample to those in modern predator-prey relationships can be a useful line of evidence to infer the agent of faunal accumulation. Analysis is based on investigating how the age of species differs in archaeological and modern context (Klein 1982; Klein and Cruz-Uribe 1984; Stiner 1990:307). Humans are thought to hunt selectively and balance recruitment and mortality to maintain population stability through several years in order to preserve the breeding population (Lyman 1994).

Differences may exist between the ages of prey selected by humans and dingoes. The presence of high proportions of juveniles of the larger species may indicate canid based attrition and predation. Ecological studies indicate that juvenile Macropods are killed more frequently than adult Macropods. In the open landscapes of NSW, almost all red kangaroos killed by a pack of dingoes were juveniles, and weighed less than 18 kg (96.4%) and were mostly females (81.3% of prey); while in the closed forests in NSW, a preference for dependent juveniles was identified (32% of prey). However no sex preference was identified (Corbett 2001:115). Packs of dogs can, and do, regularly hunt adult males; especially in drought conditions (Corbett 2001:116-7). Most Macropod mortality as a result of dingo hunting occurs at or after the permanent emergence from the pouch. However a difference
based on sex has been identified, where subadult males are more susceptible to predation as they disperse more widely from the mother, in comparison to subadult females, which are less susceptible as they remain close to the mother. The females of the larger species will evict pouch young if pursued by predator, but recent studies show this does not substantially affect their survivorship (Hume et al 1989:40).

In theory, a species characterised by a catastrophic age profile in an archaeological site could have been hunted or scavenged, but to scavenge it, humans have to encounter a population shortly after it had suffered a catastrophic mortality. These encounters would have been relatively rare (Klein 1982:153). In the Australian context they may have been associated with mass predation events of kangaroos by dingoes as a result of drought, when the predictability and abundance of game changes for both humans and dogs, and waterholes become the focal point of both (Caughley et al. 1980; Corbett 2001:100). Dingo predation can place severe stress on kangaroo populations in drought conditions (Pople et al. 2000:269). A study by Shepherd (1981) suggested a link between the abundance of kangaroos and overkill in drought conditions, after witnessing five dingoes killing 83 red kangaroos which were congregating at a waterhole during drought over a seven-week period.

"Schlepp Effects"

The differential transport of body parts to occupation sites can result in important differences in the composition of archaeological bone assemblages. If these differences exist, they may provide clues as to foraging behaviour, strategies, settlement patterns and food sharing activities (Binford 1981; Lyman 1994; Marshall and Pilgram 1991; Jones and Metcalfe 1988; O’Connell and Marshall 1989:393; O’Connell et al. 1990). Variations in the frequencies of skeletal parts in archaeological sites are often used to identify differential transport and use of skeletal elements (Perkins and Daly 1969, see also Lyman 1994:224).

Relatively few analysts have investigated schlepp effects in the Australian context (see O’Connell and Marshall 1989; Solomon 1985). The “schlepp effect” suggests that for larger animals, the further away from the point of consumption that it is killed, the fewer of its bones will get transported back to camp. This effect is of limited use in interpreting the agent of deposition in archaeological sites in Holocene Australia. Humans carried small prey (to 30 kg) back to camp, while larger wallabies and kangaroos were slung over the shoulder of the hunter, using the hind feet as a handle (O’Connell and Marshall 1989:395). In a study of transportation of kangaroo carcasses, the Alyawara (O’Connell and Marshall 1989).
dismembered only the largest kangaroos (\textit{M. rufus}, red kangaroo, mean weight females 35 kg and males 85 kg), before transport back to camp or before cooking at camp (Solomon 1985; O’Connell and Marshall 1989). O’Connell and Marshall (1989) indicate that differences in element representation at human occupation sites are likely to occur only with the largest species. However even in this case, only the feet and distal tail of large Macropods were discarded, a finding consistent with ethnographic accounts in Spencer and Gillen (1968[1899]) and Mountford (1950). O’Connell and Marshall found that the discard of these elements occurred less than 50% of the time in their study, and as such, is unlikely to produce a pattern with enough regularity to be of analytic use. The feet elements had small amounts of edible tissue and marrow and were comparatively lightweight: a negligible saving in transport cost (O’Connell and Marshall 1989:394; Walters 1984). A cooked and or butchered animal was often carried back to camp whole, as it was more difficult to manage without using the feet as handle (O’Connell and Marshall 1989:395).

In Australia male dogs can bring food back to a den, which may be located in hollow logs, or in caves and rockshelters (Lundelius Jn 1966; Newsome and Coman 1999:6; Newsome et al. 1973). Solomon’s dingo feeding trials indicated that dingoes were capable of picking up and carrying \textit{W. bicolour} carcasses (to 20 kg) for 5 m (Solomon 1985:89). Packs of dogs may eat large carcasses in situ, or disarticulate elements or portions of elements and take them back to the den site. Faeces and urine are often carefully placed as messages, used to mark boundaries and shared hunting grounds (Corbett 2001:5; Newsome and Coman 1999:6).

\textit{Differential Element Representation}

Few accounts are available which describe carcass dismemberment by hunter-gatherers at campsites. Thomson described dismemberment of Macropods into quarters to be divided and redistributed among members of the male kin (Thomson 1949a). O’Connell and Marshall described the dismemberment of carcasses\textsubscript{\textit{nto}} 10 body regions (O’Connell and Marshall 1989). Due to dismemberment, all elements may not have an equal chance of being represented in the site. Humans may also open the femur and tibia to extract marrow. These elements should be represented by shaft fragments and complete proximal and distal parts of long bones in the absence of canids (Solomon 1985). Small animals were usually brought back to camp whole. As such, they should have all elements represented; the frequencies of particular elements of small mammals cannot be used to indicate dismemberment.
Solomon conducted an extensive literature review using ethnographic and anthropologically described accounts concerning common methods of cooking hunted game. Large game (kangaroos, wallabies, dingoes, wombats, emus, bustards and turkeys) were cooked in a large pit/fire/coals/earth/sand/ant bed/stone “oven” in the ground away from the main household hearth, in which the animal was placed intact (or with feet and tail chopped off separately but may also have been cooked) (Solomon 1985:24; Walters 1984:398, 1988).

Smaller game (possums, goannas, birds, rodents, echidnas, flying foxes, bandicoots, fish, frogs and freshwater turtles), were small enough to be cooked on the campfire or be placed in the earth oven. Most animals were cooked whole in the hide (65 cases), while in only 14 cases were animals dismembered. Twenty four cases did not describe dismemberment or cooking (Solomon 1985:37). Walters (1984) gave a very similar account of large pit roasting, describing how small animals were cooked in a shallow pit, and larger animals were gutted and placed in an earth oven on a pile of sticks with small branches. The animal was thrown into the blaze to singe the fur, and then was thoroughly charred and removed from the fire. When the fire died down the singed animal was placed on its back, the coals and earth were placed on top, cooking the animal at low temperatures. This indicates that there may be little evidence of cooking of larger prey in rockshelter sites.

Direct evidence of human association with prey taxa in faunal assemblages using trace fossils (dismemberment, filleting and cutmarks; see Shipman et al. 1985; Potts and Shipman 1981, see also de Gruchy and Rogers 2002; Fischer 1995) is frequently as a key line of evidence in differentiating human and canid prey (Behrensmeyer 1989). However Solomon suggested that there would be few direct correlates of human association with skeletal elements in the archaeofaunal record (Solomon 1985). Solomon conducted an experiment in which she cooked, dismembered and processed marrow in accordance with the descriptions in ethnographic and anthropological records (Solomon 1985). Cooking animals whole in their skin softened the ligaments and tendons, and she concurred with ethnographic descriptions which stated that after cooking, meat could be pulled off the bone easily. In her experiment she was able to pull flesh off the carcass with ease, leaving only some flesh adhering to the ends of long bones (Solomon 1985:50). Most joints were able to be pulled apart by the hands alone, and as such she suggested that dismemberment cutmarks would not be present with the exception of the femoral-tibial joint and the femoral-pelvic joint as these joints were difficult to separate using the hands alone (Solomon 1985:39).

Overseas, sophisticated analyses of meat weight and marrow contributions of animals are commonly used (and see the “modified generalised utility index” or MGUI of Binford 1978; see also Lupo 1998). However, in Australia there is only one study which has provided data
concerning the meat and marrow yields of larger Macropods (O’Connell and Marshall 1986). Humans may also open the femur and tibia to extract marrow using a hammerstone and anvil. In the absence of canids, these elements should be represented by shaft fragments and complete proximal and distal ends of these elements (Solomon 1985:43). If scavengers were present however, Solomon suggested that any signatures of marrow processing will be overprinted by the reduction activities of camp dogs (Solomon 1985).

Skeletal part frequencies at archaeological sites often differ from anatomical proportions represented in the natural environment (Behrensmeyer 1993:436, 444; Blumenschine and Marean 1993; Marean 1991; Marean and Frey 1997; Marean and Spencer 1991; Marean et al. 1992). Differential representation of body regions, skeletal elements, and specific anatomical landmarks on bones may indicate canid hunting, reduction and denning behaviour. As well as analyses of differential element representation, studies of canid trace fossils (toothmarks, gnawing, fracture, other structural damage) on elements have also been used as direct indicators of predation and to infer interactions between predators and prey (Kowalewski 2002:4). Traces are often distributed non-randomly across specific elements of taxa which allow the taphonomist to inductively reason that predators may have modified skeletons (Kowalewski 2002:8). However, the question of whether the original carcasses were hunted or scavenged cannot be answered by this evidence alone (Behrensmeyer 1993:445).

Scavenging can affect surviving signatures of primary accumulation, skeletal part representation and surface modifications (Andrews 1990; Bickardt 1984; Shipman and Walker 1980). Although there are no descriptions of human-dog interactions for Holocene Australia, modern descriptions from ethnoarchaeological accounts may be used to investigate faunal attrition by camp dogs. Camp dogs may have scavenged for food or received bones from humans or a combination of the two. Dogs may have gnawed on bone where it was tossed to them or removed it to a separate area, and may have hid elements for later gnawing, licking or reduction (Kent 1993; Solomon 1985; Solomon and David 1990; Walters 1984:395). Kent observed that camp dogs of the Navaho routinely removed the meat from the bones but did not gnaw or play with them for great lengths of time. When bones were infrequently available, extensive gnawing occurred (Kent 1981). Solomon also noted that on the first day of feeding on a complete Macropod carcass, very little was left from the activity of four dogs (Solomon 1985). Hudson’s comparison of the counts of known species and elements after they were discarded by humans and after they were subjected to post depositional dog modification, indicated between 74-97% attrition of the

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elements of four prey species, with smaller bodied taxa displaying a greater degree of loss (Hudson 1993). A similar attrition rate was found at “Utopia Outstation” in Central Australia by Walters (1984), where over 97% of faunal elements deposited were not represented in the record after attrition by dogs over a three month period. Attrition was high as there was one dog for every person in the camp.

The structural density of bones also plays a part in variations in skeletal part frequencies at archaeological sites. Attrition due to structural density may lead to differential preservation of elements and may not directly reflect economic decisions (Lyman 1994:235-237). While there are general actualistic studies to draw on concerning what appear to be density mediated attrition patterns on Australian faunas in relation to dingoes, more rigorous values are not presently available to test this relationship. Previous studies of these relationships overseas are not appropriate analogues, given the differences in mechanical jaw strengths between hyaenas and canids, and differences in bone structures in prey species. Dual patterning in the carcasses of human and dingo caught prey are also likely to complicate these measures (See Capaldo 1998; Capaldo and Blumenschine 1994; Selvaggio 1998; Selvaggio and Wilder 2001).

Most carnivores use consistent methods to hunt and bring down prey. Autopsies of kangaroos killed by dingoes suggest two patterns of attack on kangaroos: 1) nipping or hamstringing the hindlegs to slow the kangaroo to attack its throat (for adult and juvenile kangaroos), and 2) running alongside and biting the dorsal thorax and neck region in juvenile and adult females of small body size (Corbett 2001:114; Dawson 1995:57). During these attacks, fractures occur to the ribs, scapulas, and dorsal and transverse spinous processes on vertebra (Shepherd 1981). Dingo reduction then begins with the abdominal region, removing the internal organs (Whitehouse 1977), moving to the area around the anus, progressing around the animal to concentrate on the soft tissues. Dingoes prefer the abdomen and thoracic tissues and hindquarter muscles (Shepherd 1981) (Appendix Table A-12). This model of dingo reduction appears to be consistent in both natural (David 1984) and captive contexts (Solomon 1985). Dingoes can gorge themselves at one sitting or reduce a carcass over several days (Corbett 2001:122).

Carcasses modified by dogs will have different body region representations to those produced by humans. David described the location of modification to a Macropod carcass from elements collected from outside a dingo Lair in North Queensland (David 1984) (descriptions drawn here as Figure 4-1). Elements from only one side of the carcass were available. For the feet, gnawing damage was centered on the proximal end (removing
phalanges and distal metatarsal 4 and 5) and the distal end of the foot (removing the calcaneum). A similar pattern was identified for the hands, where the phalanges were removed and the distal radius and ulna were removed as gnawing progressed up the forequarter. Gnawing at the olecranon of the ulna was also present. The distal mandible was damaged as a result of gnawing at the massenter muscle, the distal pelvis (ischium) was removed as a consequence of gnawing at the belly, and the articular ends of the caudal vertebrae were removed (Appendix Table A-14). These results are generally similar to other canid studies which suggest that the survivorship of less dense bones decreases as these are chosen first as they are easier to destroy and contain more grease, giving a higher net yield (Blumenschine 1988; Blumenschine and Marean 1993:289; Blumenschine and Selvaggio 1991).

Data obtained from Solomon (1985) for differential representation of body regions concurs with data obtained from captive dingo feeding trials, David’s (1984) lair data, and natural processes of carcass reduction (Corbett 2001). General patterns of reduction are presented in Figure 4-2, drawn from Solomon’s (1985) descriptions. Whole and dismembered Macropod carcasses were fed to captive dingoes. All thorax elements and forequarter elements were not returned, but hindquarter elements were returned. Solomon’s results concur well with Hudson’s conclusions regarding the differential survival of body regions after canid modification (Figure 4-3).

Differential Element Representation

The analysis of non-random representation of specific skeletal elements provides a strong line of evidence for the canid modification of carcasses (Kowalewski 2002:23; Todd and Rapson 1988). This evidence, and associated trace fossils, may also provide clues as to the nature of biotic interactions. Together these patterns can be used to infer successful and unsuccessful carcass reduction (gnawing) at specific locations that give direct access to tissue, and in situ carcass feeding.

Three studies have found similar patterning in the representation of particular elements over others at dingo kill sites. Data from Solomon’s feeding trials indicate that specific bones were less frequent than others in a prey modified skeleton. Frequently missing bones included the radius, ulna, humerus, scapula, clavicle, vertebrae and ribs (Solomon and David 1990:239). Commonly returned complete or partially complete bones included tibias, femurs and pelvi. This result is consistent with Binford’s (1981) experimental results which also
suggested the under-representation of the femur relative to the tibia, the under-representation of the proximal humerus and the distal radio-cubitus and the over-representation of pelves. Hudson reviewed the patterning in the representation of elements after dog gnawing, using available overseas data. She identified that a ranked pattern of survival was characteristic of canid ravaged assemblages, suggesting that heads survive best, limb elements (shafts) survived moderately well, and vertebrae and ribs had the poorest survivorship (Hudson 1993:301, see also Lyman 2002a). The dingo lair data suggests phalanges, vertebrae and ribs will be rare in an assemblage modified by dingoes (Solomon and David 1990:245).

**Differential Element Region Representation**

The differential survival of particular regions of long bones is indicated by several studies (Blumenschine and Marean 1993; Marshall and Pilgram 1991; Rogers 2000). Repeated patterns of modification of large samples provide compelling evidence for the carcass processing activities of a specific canid. Most studies on canids have identified the consistent gnawing removal of the articular ends and near epiphyseal portions of long bones. Hudson found that the major long bones were only represented by limb bone fragments (Hudson 1993), but the proximal humerus, distal radius and ulna, distal femur and proximal tibia survived moderately well. Solomon found a similar pattern in captive feeding trials, with the proximal and distal regions of the femur, tibia and fibula and innominate, and distal epipubic (pouch) bones destroyed.

A non-random spatial distribution of toothmarks on the regions of elements of prey taxa has also been identified (Kowalewski 2002:23). The frequencies of traces are the most widely used measure in analyses of trace fossils of predation using gnawing evidence (toothmarks, fractures) (Blumenschine and Marean 1993, Kowalewski 2002:23). The evaluation of selectivity is based on the analysis of the distribution of toothmarks across different skeletal elements.

High concentrations of marks may occur at strategic points on the articulating ends of marrow rich bones and on soft bones (Solomon and David 1990:245). In captive feeding trials, Solomon found that pits were most frequently positioned directly near the removed portions (near epiphyseal portions of the distal and proximal midshafts), while scores, furrows and striations were more frequently associated with the midshafts of the returned elements. These may be difficult to identify archaeologically, as Solomon found only half the bones clearly showed toothmarks (215 specimens) while the remainder were faint and 60
may easily have been missed (a total of 426 specimens) (Solomon and David 1990:241). Toothmarking decreased with time (Solomon 1985), possibly as a result of decrease in competition (Blumenschine and Marean 1993:288). Tooth marking data from Solomon’s feeding trial (Figure 4-3) are generally consistent with the patterns observed in other tooth marking studies overseas (compare with Binford 1981).

Although heavily marked specimens may be the result of feeding from pups, there have been no studies attempting to differentiate differences between adult or pup gnawmark frequencies (Solomon and David 1990:246). Hyaenid studies indicate that high toothmarking on midshaft fragments is consistent with low competition amongst dogs, and secondary access to bones (Blumenschine and Marean 1993:288; Selvagio 1998:193). However it is unclear whether the same pattern holds for dingoes in the Australian context. Other factors involved in the differential representation of element regions and toothmarking related to hunger of the dogs, density of the bones and species, age and sex of the prey animals (Solomon and David 1990:241).

Other Animals

A number of studies have indicated that several animals can deposit, rearrange and modify deposited bones. Termites create scratches on bone surfaces (concentrated at roughened edges and surfaces), damage cancellous bone more than compact bone, and use fresh bones more than old bones (Watson and Abbey 1986:251). Termites also increase bone preservation by increasing local pH, but also increase bone dissolution through increased soil porosity and may also facilitate the vertical movement of bone (McBrearty 1990:111, 125).

Herbivores chew long bones for nutrition. The damage they impart includes grooving, pitting, abrasion, polish and crushing (Haynes 1991; Johnston 1985). They also may create fork-like remnants of chewed long bones (Brothwell 1976; Sutcliffe 1973:430). However, while this may be an obvious taphonomic modification while the bone is intact, the diagnostic features of the chewing may be more difficult to detect after extensive fragmentation. Murids also chew various types of materials in sharpening teeth and for nutritional purposes and leave distinctive U-shaped grooves (Archer 1974b; Archer et al. 1980:121). Insects can damage bones by boring, grooving and creating pitted surfaces (Behrensmeyer 1978; Haynes 1991; Shipman 1981).
Floods

When archaeological sites and the specimens within them are found in a fluvial context, like those at Cathedral Cave, it is necessary to consider whether the specimens between different layers and units were autochthonous or allochthonous. This is particularly the case with faunal remains, which are abundant in the sandstone environment of the CQH and susceptible to movement in fluvial conditions. The movements of various objects in fluvial contexts have been studied by sedimentologists and are a useful aid to archaeological interpretation (Folk 1974; Hanson 1980; Lindholm 1987; Reineck and Singh 1986). The variables that influence dispersal and selective transport include fluctuations in current velocity, the depth of flow, the velocity gradient near the bed, the density of the bone and the rapidity of bed formation (Irving et al. 1989; Marshall 1989; Schick et al. 1989).

A large range of flume and actualistic experiments have been conducted to study the effects of floodwaters on archaeological and palaeontological assemblages. These studies indicate that a range of fluvial and specimen variables influence the transport and dispersal of bones. Data are now available from a range of different experimental and actualistic studies exploring the processes which may affect interpretations of fluvial patterning in archaeological sites. These include the post mortem transport of isolated and complete elements from a range of animal body sizes (Archer 1974a; Aslan and Behrensmeyer 1996; Behrensmeyer 1982, 1988b; Blob 1997; Butler 1987, 1993; Butler and Schroeder 1998; Dodson 1973; Korth 1979; Littleton 2000; Rybczynski et al. 1996; Schick et al. 1989; Shipman and Rose 1983; Vooohries 1969; Wolff 1973), tests of the hydrodynamic effects of specimen size (Gifford-Gondalez 1989a, 1989b; Napawongose 1981), variations in transport of wet and dry, articulated and unarticulated elements (Coard 1999) and position in the fluvial environment (Baird 1982:272; Hanson 1980). The range of specific correlates used in this analysis to investigate the effects of fluvial processes at Cathedral Cave is discussed further below.

Post Depositional Processes

Thermal Modification

Thermal modification is discussed under the realm of post depositional processes as the analysis of the thermal modification patterns in the sites of the CQH suggest the
unintentional modification of faunal specimens at reoccupation events. Analysis of the distribution of thermal modification evidence is important as it can inform analysts about both the intentional and unintentional heating of faunal specimens (Bennett 1999), from which inferences concerning occupation frequencies can be made. Most experimental studies have aimed to generate accurate criteria which can be used in the identification of heating, and reliable assessments of the context in which thermal modification occurs (Stiner et al. 1995:224).

Studies explore the effects of a range of variables including different temperatures, duration of the fire, variations related to the age of the bone, species variations, and whether elements had flesh attached at the time of thermal modification (Bennett 1999; Buikstra and Sweagle 1989:250; Buikstra and Ubelaker 1997; David 1990; Gilchrist and Mytum 1986; McCutcheon 1992; Nicholson 1993:413; Shipman et al. 1984; Stiner et al. 1995). Experiments investigating the thermal modification of faunal remains have been made by several researchers and have returned generally consistent results (Bennett 1999; Gilchrist and Mytum 1986; Grayson 1984; Herrmann and Bennett 1999; McKinley 1994; Stahl 1996:52; Stiner et al. 1991; Stiner et al. 1995). Common taphonomic criteria include colour change on elements, which is useful only in a very general way to indicate the range of temperatures to which a bone had been heated (Bennett 1999; Buikstra and Swegle 1989; Knight 1985; Nicholson 1993; Shipman et al. 1984; Spenneman and Colley 1989; Stiner et al. 1995).

Analysts have stressed the importance of identifying the timing of the thermal modification relative to deposition and burial (Stiner et al. 1995; Lyman 1994). The experimental data suggest that specimens can become thermally modified either intentionally or unintentionally at discard or while buried in sediments (Grayson 1988; Lyman 1994; Stiner et al. 1995) (Table 4-2). For example, the sediments between 1-5 cm depth beneath fires can reach between 200 °C and 500 °C. The mean temperature experienced within 1-4 cm depth was 400 °C (Bennett 1999; Gilchrist and Mytum 1986). Bennett’s study indicates that sediments can maintain temperatures of 400 °C for 50 hours after the fire had been extinguished (Bennett 1999). The careful analysis of the extents of burning (e.g., the various levels of calcination and carbonisation; Stiner et al. 1995), ratios of carbonisation and calcination over the site as a whole, and in levels of the site can be used to provide information about the nature of the fires in the site through time: including the consistency of their location, and their intensity and duration (Gilchrist and Mytum 1986; Herrmann and Bennett 1999; McKinley 1994; Stiner et al. 1995). Other forms of contextual data are sought...
to confirm or refute either intentional burning or unintentional burning, and are discussed further in the analytical section.

**Bioturbation**

The digging and burrowing by small animals, and the trampling of cattle and humans, have significant effects on time averaging in archaeological sites (Fiorillo 1989, 1991; Haynes 1991; Wood and Johnston 1978), and were analysed for the CQH. As discussed in Chapter 3, several analytical methods were used to investigate changes to the position and location of artefacts. These included the analysis of size distributions of specimens in layers, size grading (Bocek 1986:591, 601) and anatomical and mechanical refitting of specimens from each layer from each site. There have been some influential studies, both in Australia and overseas, on the effects of trampling of vertebrate remains by cattle (Fiorillo 1989:62) and humans (Gifford-Gonzalez et al. 1985). A range of variables have been tested including the age of bones (fresh or dry), the moisture content of the sediment (Graham 1993:110), sediment type (Olsen and Shipman 1988), and changes to the compaction of sediments from trampling (Gifford-Gonzalez et al. 1985; Nielson 1991).

**Physical Weathering**

Faunal specimens in the CQH may display considerable weathering due to high temperatures, aridity, flooding and sudden contrasts in climatic regimes. The weathering stage of bones in an archaeological assemblage is a frequently studied taphonomic indicator, used to estimate the duration over which a faunal assemblage accumulated. There have been several actualistic and experimental studies on weathering of vertebrate materials (Behrensmeyer 1978; see also Johnston 1985; Andrews 1990; Andrews and Cook 1985; Hill 1976, 1989a). The most influential study was Behrensmeyer's (1978), which examined weathering in the bones of animals of up to 5 kg weight in the African savannah. Bone weathering normally results from exposure to air, wind, sun, rain, temperature and chemical fluctuations and or freeze/thaw cycles. Under these conditions, the smooth bone cortex degenerates from the outer surface toward the interior, causing cracking, splitting and exfoliation, leading eventually to the complete disintegration of the bone (Behrensmeyer 1978; Gifford 1981; Haynes 1988; Lyman and Fox 1989). Weathering stages are used to indicate the length of time bones are exposed on the surface prior to burial. Recent studies have also been conducted with bones of smaller animals in rainforests (Tappen 1994; Tappen and Peske 1970), and larger animals in temperate England (Andrews 1990; Andrews 1990; Andrews 64
and Cook 1985; Inkpen and Jackson 2000), Nebraska (Fiorillo 1989) and Wisconsin (Tappen and Peske 1970). The same general weathering patterns were identified, but occurring over a longer time scale in temperate environments. This suggests that weathering is related to changes to the structure of the bone itself, and to local environmental conditions (soil pH, amount of shade, exposure to sunlight, wetting/drying, extremes in moisture and temperature and ultraviolet light) (Behrensmeyer 1978; Miller 1975:217; Tappen, 1994:667; Tappen and Peske 1970).

A number of issues have been raised about the interpretative meaning of weathering stages and estimates of elapsed time (see Lyman and Fox 1989 for detailed criticism). The weathering of bones in subsurface contexts remains largely unstudied, although indications suggest that in these conditions bones weather much more slowly than unburied bones, but there is no reliable way to distinguish between them (Lyman 1994:360; Stiner et al. 1995). Although Tappan and Peske suggest that buried bones have less tendency to crack (Tappen and Peske 1970:384).

Burial Processes

Compaction

Compaction is a significant taphonomic variable affecting deeply buried specimens in sites. The compressive weight of overlying sediments results in compaction, and the fracture and deformation of specimens (Darwent and Lyman 2002; Hannus 1989:400; Shipman 1981). Compaction can also result in the concentration of artefacts, due to increased bulk density and an increase in the number of specimens per unit volume of sediment (Kidwell 1986; Lyman 1994:424; Shipman 1981). When deposition is rapid, sediment pressure can crush or break buried faunal remains; however slower deposition can create deformations in specimens without breaking them (Shipman 1981).

Compaction was considered to be a significant factor at Cathedral Cave where bones are buried within a deep (5 m) deposit over 210 m², the weight of which increased during flood events due to the added weight of water. At Cathedral Cave the 14 stratigraphic layers vary in depth, extent and compaction. The relatively shallow (<50 cm) deposits at Rainbow and Wanderer’s Caves were not expected to have significant sedimentary alterations. As discussed in the previous chapter, a range of tests were performed to assess the potential taphonomic effects of compaction and compression of the sediments, including bulk density,
sediment consistence tests, and assessments of organic content using loss on ignition tests (LOI). A number of techniques were used to investigate in situ fracture and distortion, which are described fully below.

**Chemical Modifications**

Recent years have seen a rapidly expanding body of research concerning the chemical composition, mineral nature, chemical modification and diagenesis of bone within sediments (Grupe 1995; Hedges and Millard 1995; Karkanas et al. 1999; van Klinken and Hedges 1995; Linse 1992:329; Meyer 1991; Nicholson 1989, 1996; Schiegl et al. 1996; Sillen and Parkington 1996; Stiner et al. 2001; Turner-Walker and Parry 1995; White and Hannus 1974a). This research indicates that bones can weather in situ in both alkaline and acidic sediments as a result of microenvironmental variables including moisture, oxygen and temperature, which affect sediment pH and the rate of bone diagenesis. A deposit subjected to spatially different temperature or moisture conditions will exhibit more than one pH value (Linse 1992:329). In addition, specimens at the sites were diagenetically modified by staining from manganese oxides (black dots and dendrites) or iron oxides (Shahack-Gross et al. 1997:440). Manganese oxides are formed by manganese oxidizing bacteria, which use the bones themselves as a source of nutrients, and prefer moist environments that are anaerobic with a near neutral pH (Shahack-Gross et al. 1997:440). In this analysis, calcium carbonate replacement, chemical leaching and manganese staining was considered (Halliday 1992:102; Stein 1992:196).

**Excavation and Curation Processes**

**Excavation**

Zooarchaeologists have long recognised that the use of field sorting, and larger sieve sizes create size biases. The use of 1/4 inch (6.35 mm) 1/8 inch (3.175 mm) sieves causes the loss of elements of small and medium sized animals, or small elements of larger taxa, and has important implications for interpretations of faunal samples (e.g., taxa present, element abundance, and taxonomic relative abundance) (Brain 1981; Butler 1993; Cannon 1999; Casteel 1976; Grayson 1984; James 1997: 385-397; Kidwell et al. 2001; Shaffer 1992; Shaffer and Sanchez 1996, 1999; Stahl 1996; Thomas 1969). Archaeological material was collected from the 3 mm sieve, although some fragments of bone were not recovered (Beaton 1975 unpublished fieldnotes). Jones found that between 70-90% of mammal bones
of animals in the size range 5 g to <100 g were lost in a 1/4 inch screen, and although considerably less bone was lost in a 1/8 inch screen, 40-70% of elements from animals weighing <100 g to 25 kg were lost (James 1997:386, Figure 1). In Australia, animals of small size (200 mm body length, including bats, murids, dasuypids) and medium sized animals (200-400mm body length, including echidna, bandicoot, possums) may be underrepresented in comparison to larger animals (wallabies, kangaroos) (Menkhorst and Knight 2001; Strahn 1995). Samples were not wet sieved in the field or laboratory at the time of Beaton’s excavation.

Curation Issues

Transport and storage of the collection is likely to have caused some fragmentation and destruction of some of the specimens over the last 30 years (see Flessa et al. 1992 for transport related fragmentation of shells). Biases have also been created as some cranial elements from Cathedral Cave, previously identified by Archer and van Dyck in 1975, do not appear to be present in the collection today, and their whereabouts are unknown. In addition, bone implements could not be relocated. These losses mean that reassessment of arguments concerning these specimens can not be made at present (see also Costamango 2002).

Analytic Methods

Identification of the Sample

The range of animal species potentially contributing to the faunal assemblages of the CQH over the last 4,000 years were identified by reviewing faunal species which have been identified from other archaeological deposits in the CQH and wider region (Appendix Table A-9). The faunal species extant in the region today were also collated (Appendix Table A-8; Strahn 1995).

In order to make a correct interpretation of taphonomic processes and mode of preservation, it is necessary to have knowledge of the structural features or morphology of the original skeleton of various species. Species identifications were based on direct one-to-one comparisons of archaeological specimens with osteological reference material in the collections of the Department of Prehistory, Research School of Pacific and Asian Studies, at the Australian National University, and at the CSIRO Division of Wildlife Research, Gunghalin, Canberra. The collection included juveniles and adult specimens of both sexes,
to assess variations in size and sexual dimorphism, although sexing was not attempted (Coy 1978). Several texts with osteological photographs and descriptions of osteological landmarks were consulted (Bass 1995; Cosgrove 1999; Cox and Mays 2000; Coy 1978; Mays 1998; Merrilees and Porter 1979; Triggs 1984, 1988, 1996; White 2000).

It is also important to confidently identify taphonomic traces and identify the likely actor which emplaced them. Taphonomic modifications were identified using a one-to-one comparison of specimens altered by known taphonomic agents and processes. In Australia, these included specimens in the RSPAS modified by dingoes (David 1984) and open fires (David 1990). Photographs of specimens altered by specific taphonomic modifications in the Australian context were also consulted (Hall and Jones 1990; Walshe 1994a). In addition, photographs of taphonomic modifications reported in the literature were used (e.g., Archer 1974a, 1974b; Bass 1995; Behrensmeyer 1978; Binford 1981; Buikstra and Ubelaker 1997; David 1990; Gifford-Gonzalez 1989a, 1989b; Haglund and Sorg 1996; Haynes 1980; Johnston 1985; Long et al. 2002; Marshall 1989; Oliver 1989; Solomon 1990; Tappen 1994; Walker 1995).

Each specimen was examined under an x10 hand lens under a strong bi-directional light, which was sufficient to detect diagnostic taphonomic features. Following Blumenschine et al. (1996:495), each specimen was systematically examined on all surfaces (medullary cavities, cortical and spongy tissue and specimen cross sections) at different angles to incoming light. Specimens were not cleaned and were not wet sieved. All specimens were weighed to 0.01g on an ISSCO balance and measurements taken using a digital calliper calibrated to the nearest 0.01mm.

Analytic Variables

The detailed study of the processes and the effects on bone surface modification of archaeological faunal elements has become of utmost importance in zooarchaeological analyses of vertebrate remains as an aid to assessing taphonomic issues associated with site formation processes and human behaviour (Fischer 1995:7; Lyman 1984:259). As taphonomic research has increased, the range of criteria used as taphonomic attributes and signatures have also increased (Andrews 1990; see also Brewer 1992).

Reliable interpretation of the faunal remains rests on understanding the processes that led to the deposition, preservation and transformation of the remains. Data consistency and integrity were checked by including forms of redundancy during data collection to increase
the accuracy of determinations. For example three forms of redundancy were built in, including entering the region present on the long bone specimen, the anatomical landmarks present, and the percent completeness of the specimen. These forms of redundancy were especially useful when checking data entry, and were useful when conducting various analyses of material. Some taphonomic attributes are more subjective than others. For this reason, a number of taphonomic attributes were used to increase confidence in identification, and to cross check interpretations using complementary lines of data. Accordingly, a large and diverse range of attributes were collected in the faunal analysis, and are outlined in Appendix Table A-7.

**Canid Signatures**

An impressive amount of archaeological research has documented bone accumulation, modification and destruction resulting from the actions of various carnivores (Archer et al. 1980; Andrews and Evans 1983; Binford 1981; Blumenschine 1986, Blumenschine and Marean 1993; Brain 1981; Bunn 1983; Capaldo and Blumenschine 1994, Marean and Spencer 1991; Hockett 1996; Lupo 1995:289; Payne 1983; Schmitt and Juell 1994; Wheeler and Jones 1989). Modifications in predator assemblages are related to the way each predator kills and eats its prey, and include breakage, digestion and differential representation of body regions and elements.

A range of taphonomic indicators of canid digestion were included in this analysis including compression caused by mastication and by the muscles of the digestive tract, pitting from digestive corrosion (including rounded and polished fracture edges), digestive staining (yellow browns, strong browns, or white) and adhering scat matrix (including hair and visceral matting) (Schmitt and Juell 1994). These taphonomic effects have been identified in feeding experiments with dogs, hyaenas, wolves and foxes (Binford and Bertram 1977; Binford et al. 1988; Brunner et al. 1975, 1976; Crandal and Stahl 1995; Marean and Spencer 1991; Payne and Munson 1985; Kippel and Snyder 1987; Stallibrass 1984). However the ease of identification of these attributes is affected by weathering, solar bleaching and dissolution in acidic sediments. Adhering matrix has been found to decompose with age and depth in the CQH sites 50 cm below the ground surface in pH of 5.5. In this case, the confidence of scat bone identification was increased by evidence for digestive modification. The survivorship of digested bones may also be reduced once the protective covering of the scat has decayed (Andrews and Evans 1983:306; Stahl 1996:49). Interpreting the faunal remains within scats (e.g., species, age) is useful in identifying the actor of defecation, and
provides environmental information concerning the territorial range of the canid over the previous 48-52 hours (Solomon and David 1990:245) (refer Figure 4-4 to 4-13).

Carnivores break bones by static loading (see Wroe et al. 2004), and generally gnaw at the ends and chew the shaft of the long bone, eventually collapsing the cylinder of the bone. This process leaves diagnostic furrows, punctures, scoring and pitting on the bone (Binford 1981; Johnston 1985). A range of traces indicating carnivore gnawing was collected in this analysis. These modifications typically include scores, furrows, pits, punctures and ragged, chipped, sinuous, scalloped and crenulated edges, polish and conchoidal flake scars and bone flakes (Binford 1981; Blumenschine 1988; Blumenschine and Marean 1993; Blumenschine and Selvaggio 1991; Johnston 1985; Shipman and Rose 1983; Solomon and David 1990). Australian experimental trials of dingo predation have also noted that toothmarks, pitting, carnassial marks, incisions and scores are commonly located at or near areas of maximum meat (muscle attachment areas), and near epiphyseal regions on Macropod tibias and femurs (Figure 4-3) (Solomon and David 1990:239). Element frequencies at the CQH sites were compared with data from Solomon (1985), Solomon and David (1990) and Hudson (1993).

**Human Signatures**

Taphonomic traces indicating butchery, and the human reduction and modification of animal carcasses into consumable parts (Lyman 1987:252), are often used as direct lines of evidence indicating the human association with faunas. Although butchery evidence was expected to be rare in the CQH faunas, as it is with other studies (Bar-Oz et al. 2002; Cruz-Uribe and Klein 1994:42), evidence of human butchery was analysed. The main forms of data collected included cutmarks (Shipman 1981, see also Abe et al. 2002) and evidence of percussive force on marrow rich faunal elements.

Experimental studies have identified several types of modifications made to bone surfaces by stone tools (Shipman and Rose 1983, Shipman 1981). A range of criteria have been established concerning the identification of cutmarks based on morphology (Olsen and Shipman 1988), and interpretation of the activities that these marks represent (e.g. skinning, disarticulation and filleting, Binford 1981:47) identified by anatomical location, orientation, repetition and purpose (Guilday et al. 1962; Lyman 1987; Noe Nygaard 1989; Olsen and Shipman 1988:550). In this analysis, cutmark criteria identified by several researchers were used (Guilday et al. 1962; Lyman 1987; Noe Nygaard 1989; Shipman 1981; Olsen and Shipman 1988:550), and were quantified by counting the number of cutmarks, and the
documentation of species, age, element and cutmark location in order to assess anatomical purposeness (Lyman 1994), and compared with ethnographic or anthropological records.

There are several complicating factors in the analysis of the meaning of butchery marks. These include 1) variation in marks resulting from the condition of the carcass when processed, 2) the force required to butcher (Binford 1984), 3) a lack of systematic butchery practices, 4) differences between dismemberment and the general removal of meat (Bunn et al. 1988), 5) differences between butchery procedures based on prey size (Lyman 1994:311), 6) carcass anatomy, and 7) cultural or technological causes including transport considerations (Lyman 1994; Yellen 1991). Cutmarks should also be clearly differentiated from those made by rodents and carnivores (Cruz-UrIBE and Klein 1994), and those made in excavation (see Fischer 1995:46). Humans also break bones in a variety of ways, mainly through dynamic loading, which leaves diagnostic fracture types on the bone from point loading, including percussion pits, flake scars, spiral/helical fractures and variations due to direct rest on an anvil, and evidence of force waves including hackle marks and ribs (Agenbroad 1989; Blumenshine and Selvaggio 1991; Irving et al. 1989; Johnston 1985; Lyman 1987).

Analysis of Dual Patterned Assemblages

Many of the criteria addressing predator prey relationships are insufficient when applied alone and, ideally, multiple lines of evidence should be used (Kelley et al. 2003; Kowalewski 2002:9). Because the bone reduction strategies of humans and carnivores can appear similar based on gross appearance, a number of attributes have been developed, and are commonly used to distinguish between carnivore and human effects on the fracture of bones.

Canid gnawing modifications must be carefully identified as in some cases they mimic human butchery evidence. Fine striations and conchoidal flake scars are modifications made by carnivores which are the most likely to lead to potential confusion with cutmarks and conchoidal flake scars from hammerstone percussion (Fischer 1995:38; Pots 1988:84). The majority of cases can be distinguished by analysts, through the use of size based criteria (Blumenschine et al. 1996). Canid produced flake scars and flakes are generally smaller than those produced by hammerstones, although careful consideration needs to be given to overlapping flake scars (Bunn 1989; Capaldo and Blumenschine 1994). Cutmarks tend not to follow the contour of the bone, are shallower at the ends than in the middle, produce grooves with rounded or flat bases, are of uniform depth and display small sideways...
deviations and undulations (Fischer 1995:39). Cutmarks however, can display uneven depths due to thickness of muscle and ligaments, or the size of the flake tools.

Several analytic tests of the agent of capture and modification of prey were assessed, using the range of species in the site, their body sizes, age distributions and skeletal part representation. The number of identified specimens by species, age and size displaying evidence of canid modifications were compared to modern ecological data for dingo predation. Species were identified using osteological comparative collections; age was determined by assessing the extent of epiphyseal closure; and taphonomic data for canid gnawing and digestive modification included those attributes outlined above. The age structure of Macropods was identified using cranial remains where available (after Hartzell et al. 1999; Lentle et al. 1998). Modifications to the faunas included evidence of human butchery and percussion and thermal modification, while the extent of canid overprinting was assessed by investigating the under-representation of body regions (Hudson 1993), and the differential representation of particular regions of elements. Body regions were defined as the head, chest, back, forelimb, hindlimb, feet, hands, and those that could not be identified (after Hudson 1993). The analysis considered the general patterns that were a result of density mediated attrition (Binford 1981; Lyman 1994:401; Todd and Rapson 1988), although more sophisticated tests are not yet possible in Australia. The trends in the three archaeological sites were compared to data concerning preferred reduction areas indicated by ecological, experimental and overseas ethnoarchaeological patterns (as discussed above). However agencies identified by these criteria remain equivocal as different accumulating mechanisms possess similar signatures (Stahl 1996:51).

**Fluvial Correlates**

A range of methods are now available through which to analyse the effects of floods on archaeological components. At Cathedral Cave, several analyses were conducted to assess potential fluvial winnowing of the faunal component, including analysis of Voohries groups (Voohries 1969), shape (Frostick and Reid 1983; Dodson 1973), rounding (Courty et al. 1989; Stein 1993:362), abrasion (Gaudzinski 1995; Hanson 1980; Shipman 1981; Shipman and Rose 1983, Shipman and Rose 1988; Stein 1993:362), and the removal of external laminar bone (Bromage 1984; Gifford-Gonzalez 1989a:192; Shipman 1981). Sediment and fine grained organics embedded in fossae and trabeculae formed an important line of evidence through which to identify specimens affected by water moving over the site (Behrensmeyer 1982, 1989; Boaz and Behrensmyer 1982; Dodson 1973; Frostick and Reid 1983).
1983; Miller et al. 1977; Schick 1986, 1987, 1992). Analyses of the vertical and horizontal variations in size patterning were also conducted (Boaz and Behrensmeyer 1976; Trapani 1998). A range of other common tests of fluvial activity in archaeological contexts, including orientation (Behrensmeyer 1991; Jones and Dennison 1970) could not be used here. Orientation data was not collected at the time of excavation, and settling experiments were also unable to be conducted as these would have fragmented specimens in the collection. Estimates of settling velocities (based on using quartz equivalency) from animals of similar size were used instead (Behrensmeyer 1975; Fiorillo 1991; Korth 1979).

*Thermal Modification*

As discussed above, thermal modification to faunal specimens can occur as a result of incidental or intentional exposure to heat. Multiple factors must be considered when determining the relationship between the observed archaeological bone condition and conditions when burnt (Buikstra and Sweagle 1989:249; Reinhard and Fink 1994). A range of contextual data were analysed to identify the timing of thermal modification relative to deposition and burial. The results of Stiner et al.’s experimental data (1995:231, table 6, presented here as Table 4-5) were used to interpret the thermally modified specimens in the CQH sites as their data were presented in a manner amenable to analytical comparisons with archaeological data. The extent of thermal modification was coded after Stiner et al. (1995) as unburnt, slightly burnt, <50% carbonised, >50% carbonised, <50% calcined or >50% calcined. Ratios of calcination and carbonisation were derived and overall patterns for each site as a whole, and variations in units and levels, were compared with Stiner et al.’s experimental set (1995). However, given the nature of the processes involved, this was not expected to be a particularly sensitive indicator, providing a general measure of the intensity and duration of heating for those specimens that were burnt.

In addition, the extent of burning was analysed by animal size, age, species, and element, in combination with other lines of evidence for carcass reduction (e.g., butchery) (Gifford-Gonzalez 1989; Lyman 1994:389; Stahl 1996:52). Timing of the burning event may also be indicated by burning over a fracture surface and interior medullary cavities (Johnston 1989), although there may be some ambiguity about the timing of the fracture using the latter criteria, given experimental data which indicates that thermal stresses alone create fracture of specimens (Stiner et al. 1995, Buikstra and Sweagle 1989). The post depositional differential preservation of burnt and unburnt specimens (von Endt and Ortner 1984) and pH
(Buikstra and Sweagle 1989; Knight 1985; McCutcheon 1992:350) were also assessed at each site, and are discussed in detail in Chapters 8 to 10.

In addition, a cross-check of the argument for in situ thermal modification of buried specimens was conducted. This was achieved through the analysis of specimen colours created by thermal modification, and the use of morphological alterations that bone undergoes when heated to certain temperatures (e.g., distortion, shrinkage, cracking and checking) (Buikstra and Sweagle 1989; Mays 1998). Both these pieces of information provide information on the general temperatures attained by the bone, and the condition of the bone at the time of burning (i.e. fleshted, defleshed; Buikstra and Sweagle 1989).

**Bioturbation**

A range of tests were conducted to assess the effects of bioturbation and trampling. Identification of trampling was based on analysis of the size distributions of specimens (Moyerson and Cahen 1977; Peacock and Fant 2002; Villa and Courtin 1983), shape variations with depth (Gifford and Behrensmeyer 1977) and associated evidence of localised or homogeneously distributed, randomly oriented, multidirectional and variously sized, high density marks on individual and groups of bones (Andrews and Cook 1985; Behrensmeyer et al. 1989:116; Fiorillo 1989:70; Gentry-Steele and Carlson 1989:425; Olsen and Shipman 1988:537). However the latter correlate is somewhat ambiguous indicator because of the many taphonomic processes which can also mark bones (Behrensmeyer et al 1989; Fiorillo 1989:66; Fischer 1995:35; Oliver 1989). However, the majority of the marks produced by sediments do not lead to analyst confusion and can be easily distinguished by the absence of several features (Andrews and Cook 1985; Behrensmeyer et al. 1989; Fiorillo 1989, Fischer 1995:35). Fiorillo’s study showed that highly weathered bones (weathering stage 4-5) showed few scratches and tended to crumble easily, while those least weathered bones retained scratches. Refitting analyses were used to investigate trampling related fracture and vertical movement of faunal remains.

**Compaction**

Fragmentation of faunal specimens is usually assessed through ratios of NISP:MNI ratios per skeletal part (Klein and Cruz Uribe 1984). Because this test does not directly assess if greater fossil density with depth is a function of decreased porosity with increasing depth (Retallack 1990), other tests are usually performed, including the analyses of NISP of
isolated teeth and mandibles or other small dense bones (e.g., periotics, phalanges, Lyman 2002a). However these analyses could not be performed at Cathedral Cave as the underlying assumptions of such tests were markedly violated. Most dense bones in wallaby and Macropod carcasses are routinely removed by carnivores (see also Marean 1991), while isolated teeth specimens at Cathedral Cave may have been deposited or become dislodged from mandibles, by fluviatile events (Boaz and Behrensmeyer 1976). Due to these issues, specimen deformation was used to investigate compaction deformation, although no specimens with deformation were identified in the deposits.

Weathering

The weathering stage of each specimen at the sites was identified by categories based on Behrensmeyer’s (1978) experimental data. Sub-samples of specimens from the CQH sites were selected to be comparable with Behrensmeyer’s experimental set. Only specimens which had not been modified by thermal modifications or canid modifications were included in the analysed sample. The mean maximum weathering stages (MMWS) for all specimens in the site were determined for the site as a whole, and by units and layers. Behrensmeyer indicated that variations in weathering rates, indicated by different weathering stages, may occur between animals of different body sizes and elements within these body sizes (Behrensmeyer 1978, 1991:303).

Variations in the temporal and spatial distribution of weathered bones was also conducted, to investigate possible micro-environmental changes, and cross checked against rates of sedimentation. These tests provide lines of evidence concerning different microenvironmental conditions, exposure durations and variations in accumulation times (Behrensmeyer 1978:161; Lam 1992). The weathering stages displayed by specific elements of each species were analysed separately, providing independent samples of data (Lyman 1994:361). Differences in the weathering stages of anatomical refits were investigated, however no examples were found. Like butchery and canid taphonomic traces, mimics of weathering modifications can also occur and must be considered. Mimics creating weathering like cracks include trampling and thermal modification (Gifford-Gonzalez 1989a; Stiner et al. 1995:233). The preservational biases relating to weathering stages at each site were considered and are discussed in detail in Chapters 8-10.


Quantification

Most of the analyses used NISP, and MNI and MNE. Procedures used to obtain a measure of the relative abundance of each of the faunal species in the sites followed those outlined in Bailey and Grigson (1987), Gilbert and Singer (1982), Grayson (1984), Klein and Cruz Uribe (1984) and summarised in Lyman (1994). MNE were calculated using anatomical landmark data (refer Appendix Table A-7).

Tests of “Analytic Absence”

Problems in the identification of specimens increase with the degree of fragmentation of the bones, with low frequencies of identified faunal remains indicating taphonomic attrition (Hope 1980:44; Mountain 1999). Identifiable fragments tend to be larger than non-identifiable fragments (Stiner 1994). The minimum size of identifiable specimens will vary from taxon to taxon and from skeletal element to element. This analytic absence of elements and taxa has significance for the analytic techniques. Analysts must consider whether elements, species and ages are rare due to differential fragmentation or are a reflection of specimens at the time of deposition. Analysts who interpret element frequencies of a single taxon now recognise that some skeletal elements may be unidentifiable, or “analytically absent” (Lyman 1994) despite their actual presence in a collection. To control for this effect, the faunal data was analysed to determine the extent to which burning, weathering, soil acidity and canid modifications were contributing to specimen size reduction and reduction in specimen identifiability.

Initial results of my analysis indicated that burning and weathering have a negative effect on identifiability (for example, Table 4-3 for apparent impact of burning on identifiability), with further analysis indicating that the prime determinant of identifiability is the completeness of the specimen (see Table 4-4). Smaller fragments of bone are less likely to be identified, and there is a dramatic drop in identifiability when specimen completeness falls below 25%. Most of the contribution of the other factors to identifiability relates to their reduction of the faunal remains, although weathering to stage 5 and calcination appears to have had additional effects (Table 4-5 and Table 4-6). The effects on identifiability vary with the type of canid modification, involving the selection of elements, the mechanical reduction of bone, the swallowing whole of some smaller elements and acid erosion in the gut (Table 4-7). The dominant effect of canid modification is the systematic reduction of bones, particularly long bones, reducing the overall identifiability of the assemblage. In all
cases, reductive processes will increase the number of fragments in the archaeological assemblages of the CQH and reduce the identifiability of specimens to specific analytic levels.

This reduction in identifiability has two analytic effects. First, it reduces the sample size available for comparisons (e.g., animal age). Second, it will cause a systematic underestimation of the presence of smaller, less dense and more fragile bones (Table 4-8). The percentage of specimens that are "unknown" in a given category provides a useful measure of confidence in these interpretations: the more specimens that are unknown, the greater the chances that smaller bones, and animals of small body size, may be underrepresented and analytically underestimated.

Tests were undertaken to determine if specimen counts could be used as a valid measure for the faunal analysis. Two cross-checks were used: 1) the total weight of bone, and 2) the total estimated completeness of specimens. Bone weight has the advantage of being unaffected by reductive processes: a given bone has the same weight even though it has been broken into many fragments. However, bone weight has its own inherent bias because basic bone weights vary considerably from element to element and species to species. Estimated completeness is a more generally useful score because it is unaffected by degree of fragmentation and is not biased by size differences between bones. However, estimated specimen completeness is also potentially affected by analyst error.

Two tests were performed to determine the reliability of estimates of specimen completeness. Bone completeness was compared with mean weight of Petrogale femurs as a controlled case. A good agreement was noted between weight and estimated completeness (see Table 4-9). Landmark data was used to estimate completeness using the formula:

\[ \frac{\text{# landmarks on specimen}}{\text{maximum # landmarks for the element}} \times 100 \]

For example, in this study, 14 osteological landmarks were coded for Petrogale femurs, a femur specimen with five landmarks would have a landmark completeness score of 35.7%. However the total number of landmarks varies by element, for example ribs only have three, which creates more coarse-grained range of landmark scores. The difference between the estimated completeness score and landmark based completeness score was calculated. Ninety percent of specimens had a difference of \( \pm 10\% \), and the specimens with larger differences were generally those elements with a small number of defined landmarks. Pearson’s correlation coefficient was calculated between the estimated specimen
completeness and the landmark based completeness ($r = 0.84, p < 0.01$), revealing a strong correlation between the scores, indicating that the estimated completeness score was a reliable measure.

Stacked bar charts were created examining the broad patterns within each site (e.g., burning extent by layer) using specimen counts, sum of bone weights and sum of completeness scores. Overall, there was extremely close agreement between the specimen counts and sum of completeness, with a predictable difference when using bone weight. The close agreement between specimen count and the sum of completeness was in part due to the very similar degrees of reduction of bone over the three sites as indicated by mean completeness in Table 4-10. Overall it was concluded that specimen count was an adequate basis for analysis and comparison within and between the three sites.
Chapter 5: Lithic Taphonomy Methods

Taphonomic analyses should include all objects and their spatial relationships that derive from living systems (Robins and Stock 1990:93)

Introduction

A wide range of taphonomic agents and processes act on stone artefacts (Gillespie et al. 2004; Hiscock 1985:82, 1990a:36, 1993, 2002; Hiscock and Clarkson 2000), the analysis of which offers a useful additional line of evidence that can be cross-correlated with faunal and macrobotanical remains, and provide crucial data regarding human behaviour and site formation processes. The taphonomic history of lithic artefacts begins with material procurement, through manufacture, use and alteration, to discard, burial, diagenesis, excavation and analysis (Burroni et al. 2002; Hiscock 1985, 1990a, 1990b; McBrearty et al. 1998:106).

The lithic assemblages from the three CQH archaeological sites were analysed to investigate possible taphonomic agents involved in their transformation. No prior taphonomic analysis of the lithic component of the three assemblages had been conducted. The first half of this chapter discusses the major processes that shaped the taphonomic history of the lithic assemblage in the CQH sites. The taphonomic processes of interest were 1) trampling, 2) thermal modification, 3) fluvial movement and winnowing, and 4) weathering. A number of factors also affecting the operation of taphonomic processes were considered including sedimentation rates, overburden and compaction of the deposit. The second half of the chapter presents methods used to analyse the taphonomic and technological aspects of the lithic component of these sites. Results of the lithic analysis are presented separately in Chapter 8, Cathedral Cave; Chapter 9, Rainbow Cave; and Chapter 10, Wanderer’s Cave.

Lithic Taphonomic Pre-Depositional Factors

Human Manufacture

Human applications of force leave diagnostic traces on lithic material that allow artefacts to be distinguished from naturally produced stone fragments (Chlachula 1996a, 1996b; Chlachula and Le Blanc 1996; Crabtree 1972, 1977; Gillespie et al. 2004:616; Harding...
Based on this literature, humanly struck pieces of rock were identified if they possessed one or a combination of the following features: ringcrack, platform, eraillure scar, and positive bulb of percussion (Debenath and Dibble 1994; Hiscock 1988b). A range of different artefact types can be generated from human manufacture, including flakes, retouched flakes, flaked pieces, cores and non-diagnostic specimens. The measurements taken for these artefacts are discussed in the analysis section. Fourteen raw material types were identified as possible sources of knappable stone in the CQH region, including chalcedony, quartzite, sandstone, silcrete, basalt, shale, andesite, chert, quartz, conglomerate, granite, jasper, ironstone, siltstone, mudstones and laterite (Beaton 1981:46; Beetson and Gray 1993; Mulvaney and Joyce 1965; Quinnell 1975:2).

Microdebitage consists of small fragments of lithic artefactual material, usually 0.5-1.0 mm in maximum dimension that may be produced at knapping locations (Metcalf and Heath 1990:781), as a by-product of artefact retouch, or as a result of taphonomic processes (edge damage). These artefacts are retained in the sediment because they are too small to be removed from the site by cultural cleaning activities, and as such, provide direct evidence of on-site knapping (Healan 1995:691; Hiscock 1988b:203). Bulk sediments collected by Beaton were analysed for the presence of microdebitage. Unfortunately spatial variations in the distribution of microdebitage in these sites could not be analysed as bulk sediment samples were only obtained from one area of each site.

*Intentional Thermal Alteration*

The thermal alteration of cores and flakes has been recognised in prehistoric Australian assemblages (Akerman 1979; Flenniken and White 1983; Hiscock 1988b; Moore 2000), and probably also occurred in the CQH region. The last three decades have seen an increase in the experimental investigation of thermal pre-treatment. Most experimental research concerning the mechanical and taphonomic effects of the heat treatment of lithics has been conducted in North America (Latas 1992; Mandeville 1973; Mandeville and Flenniken 1987; Haynes 1988; Osborne et al. 2000; Patterson 1983; Peacock 1991; Schnurrenberger and Bryan 1985; Walder and Hallett 1985). The mechanics of stone artefact manufacture and diagnostic correlates have been outlined in detail (Crabtree 1972; Cotterell and Kamminga 1986, 1987; Debenath and Dibble 1994; Hiscock 1984, 1986, 1988a; Hiscock and Mitchell 1993; Moffat 1973; Pelcin 1997a, 1997b; Phagan 1976; Purdy 1975; Speth 1972, 1974; Sullivan and Rosen 1985; White 1979).
Evidence of the thermal alteration of rocks as a result of the intentional application of heat is an important line of evidence about human behaviour at a site. Heat can be controlled in the traditional setting by altering the size of the fire or altering the distance between the stone and the heat, although results can vary in prehistoric contexts due to the difficulty in controlling fires (Moore 2000). Successful heat treatment, when a stone is slowly heated to low temperatures (200-300 °C), alters a stone’s matrix, and improves the flaking qualities of the stone for the knapper (Crabtree 1972; Flenniken and White 1983; Hiscock 1993:66; Moore 2000:31). These include a reduction in fracture toughness (Domanski and Webb 1992:601), an increase in the readiness of fracture propagation (Domanski and Webb 1992:601), the promotion of longer flake removals, fewer step and hinge terminations and the production of sharper edges (Bleed and Meier 1980; Crabtree 1972; Crabtree and Butler 1964; Domanski and Webb 1992:601; Hiscock 1988b, 1993; Purdy and Brooks 1971). However thermal alteration also increases the likelihood of taphonomic transformations of artefacts (discussed further below).

**Lithic Taphonomic Depositional Factors**

After their discard, artefacts remain in the taphonomically active zone on the surface of deposits and are subjected to a range of taphonomic processes. Taphonomic processes affecting lithic remains after deposition include wind (Cameron et al. 1990), gravity (Abrahams et al. 1984; Cahen and Moeyersons 1977; Frostick and Reid 1983; McBrearty 1990:125; Moeyersons and Cahen 1977; Rick 1976; Robins 1999), termites (Cahen and Moeyersons 1977; McBrearty 1990:125), earthworms (McBrearty 1990; Van Nest 2002), and geomorphic movements of erosion, colluviation and surface wash (Balek 2002; Fanning and Holdaway 2001; Gregory 1998; Leigh 1998; Peacock and Fant 2002; Will and Clark 1996). No positive evidence for the operation of these taphonomic processes was identified in the CQH.
Humans and animals can be responsible for both damaging and moving stone artefacts via trampling. Their effects have been studied by several archaeologists (Balek 2002; Cahen and Moeyersons 1977; Cane 1982; Dibble and Holdaway 1993; Dibble et al. 1997; Gifford-Gonzalez et al. 1985; Leigh 1998; McBrearty 1990; Nielsen 1991; Peacock and Fant 2002; Stern 1980; Stein 1983; Stockton 1973, 1974, 1977, 1978; Villa 1982; Villa and Courtin 1983). In the CQH, the main agents damaging lithic artefacts were identified as humans and cattle. Cattle were prevalent in the gorge as this area was a cattle station prior to 1932. Europeans have also been identified as major taphonomic agents at these sites, particularly Cathedral Cave, which has experienced high levels of visitation since it was declared a national park in 1932 (Walshe 1999). The relatively slow sediment rates in these sites suggest that objects will remain on the surface for long periods, increasing the possibility of movement and damage (Hughes and Lampert 1977:135; Nielsen 1991; Olsen and Shipman 1988:536).

Livestock can damage archaeological material in the upper level of archaeological deposits in the region. Hall and Love (1985), studied the effects of animals in the fracture of lithic artefacts by comparing the rates of transverse snapping and edge damage on lithic artefacts in an open site trampled by cattle and humans, to the same kinds of damage identified in an archaeological site. Figure 5-1 shows that sites trampled in open contexts display higher rates of damage than those in the rockshelter. As a result of this analysis, the authors were able to comparatively assess rates of taphonomic disturbance to lithic artefacts, aiding their interpretation of site formation processes at the rockshelter. Cattle can also cause scratches on the surface of fine grained cryptocrystalline lithic materials, damage the edges of artefacts, and increase the horizontal or vertical displacement of artefacts (Hall and Love 1985).

Humans, walking on deposits during occupation, have been identified as important agents of artefact breakage and damage in many sites in Australia (Hiscock 1988a; Hughes and Lampert 1977; Jung 1992; Stockton 1977). Experimental studies have revealed a range of archaeological correlates of human trampling of lithic assemblages (Cahen 1984; Gifford-Gonzalez et al. 1985; Hughes and Lampert 1977; Levi Sala 1986; McBrearty et al. 1998:110; Nielsen 1991; Shea and Klenk 1993; Stockton 1973, 1977; Villa and Courtin 1983). These include artefact breakage (transverse snapping), edge damage (Dibble and Holdaway 1993; Dibble et al. 1997; Hall and Love 1985; Nielsen 1991), abrasion, polish and

There are several factors that influence the extent of vertical displacement of artefacts. These include the intensity of trampling (pushing the pieces further downward), the degree of compaction of the sediments at the time of occupation and at the time of trampling (compacted sediments provide resistance to object movement), variations in sediment grain size and moisture content, frequency of wetting and drying of the sedimentary deposit (Cahren and Moyersons 1977; Olsen and Shipman 1988:537; Stockton 1973, 1977; Villa and Courtin 1983:279), the thickness of the sediments covering the pieces, the size of the pieces (size sorting) (Stockton 1973:115; Villa and Courtin 1983:275), and the depth of artefact burial at the time of trampling (Olsen and Shipman 1988:537; Villa and Courtin 1983:279).

Changes in the vertical distribution of artefacts have also been identified as a result of trampling (Hiscock 1985, 1990b:123, 1993; Stern 1980). Experiments have identified that uncovered objects lying on sandy loose deposits display a normal distribution curve with depth after heavy trampling. A Poisson distribution was common to objects with a thin overlying sediment cover after trampling (Gifford-Gonzalez et al. 1985:816) (see Figure 5-2). Specimens become sorted by size, with larger pieces on the surface and smaller pieces beneath (Gifford-Gonzalez et al. 1985; Hughes and Lampert 1977; Nielsen 1991:483; Stockton 1973; Villa and Courtin 1983:267).

Heat Fractures

The processes and effects underlying the unintentional thermal alteration of lithic objects have also been studied by several researchers. Heat fracture of rock occurs when rocks or discarded artefacts lie beneath a fire or a hearth stone (Hiscock 1990a). In these conditions, rocks can be rapidly heated to high temperatures, which can result in potlids (a distinctive concave/convex fragment of stone), or can be held at high temperatures and rapidly cooled, resulting in crenation, crazing and the shatter of rocks (angular fragments) (Crabtree 1972:64; Flenniken and White 1983; Hiscock 1988b; Moore 2000:31; Purdy 1975:135-6). The uncontrolled rapid heating of stone to high temperatures results in drastic changes to the stone, reducing the knappability of the stone (Moore 2000).

Heat fractures are an important source of taphonomic information, and can also be used to inform the analyst about human behaviours at a site. Variations in the rates of both types of
thermal alteration can indicate the intensity and duration of fires and fire frequency. The analysis of the spatial and temporal concentrations of heat fractures may indicate the locations of hearths and inform about the use of space in the shelter (Hiscock 1990a:42; Hiscock and Hall 1988:65). However careful analysis of other variables is required to increase analytical confidence that the modification is related to intentional heating and not other processes.

**Lithic Taphonomic Post-Depositional Factors**

*Fluvial Deposition and Movement*

Cathedral Cave has had a complicated fluvial history, making it important to investigate the potential winnowing of the lithic component. Several studies have demonstrated that archaeological deposits can be substantially altered by fluvial processes (Graham 1993; Hanson 1980; Petraglia and Nash 1987; Petraglia and Potts 1994; Reid-Ferring 1986; Schick 1987:86, 1992:6; Turnbaugh 1978). Flowing water may bias the distribution of artefacts by removing, transporting, depositing or covering them (Petraglia and Potts 1994; Schick 1987:95; Turnbaugh 1978:593). Generally, heavier artefacts tend to move along the surface of the deposit by traction and are kept in motion by turbulence, with lighter artefacts carried in suspension (Shackley 1974, 1978). Experiments have indicated that spatial arrangements and compositions of archaeological assemblages are more likely to be modified in high, rather than in low energy fluvial environments (Petraglia and Potts 1994; Schick 1987; Schick et al. 1989; Shea 1999). Experiments have also identified a range of correlates of water flow in archaeological sites, including patterned spatial distributions, patterning in artefact size distributions, and modifications to artefacts including rounding, striations, pecking, edge flaking and crushing (Petraglia and Potts 1994; Schnurrenberger and Bryan 1985). Burial of artefacts has been found to protect deposited artefacts, retarding further winnowing (Petraglia and Nash 1987:126).

*Weathering*

Like organic objects, stones are susceptible to weathering (Debenath and Dibble 1994:10; Hiscock 1988b:325; Inkpen and Jackson 2000; Oakley 1959; Villa 1982:282). Rocks have been found to weather inward from their outer precipitation zone, layer by layer, through to an inner dissolution zone, forming a weathering rind around a relatively unweathered interior or core zone which reflects the original qualities of the raw material (White and Hannus 1974b:54). Dissolution particularly affects lithics that have high silica contents.
These are most taphonomically altered after they have been subjected to semi arid and alkaline conditions for extended time periods (Hiscock 1985, 1988a). Weathering is indicated by the presence of patina, usually of a lighter shade (Debenath and Dibble 1994:10; Villa 1982:282; Whittaker 1994). Other evidence for chemical modifications to artefacts include rounding and crumbling of artefact edges (Burroni et al. 2002; Hiscock 1988a) and polished or glossy surfaces (Burroni et al. 2002).

The presence of patina may indicate weathering but can also be used to indicate other taphonomic processes. Patinated artefacts can be an important source of information concerning the palaeoenvironment at the time of deposition, and may be used as a cross check of site formation processes, including the extent of vertical movement, stratigraphic deflation and time averaging in deposits (Debenath and Dibble 1994:10; Hiscock 1985, Hiscock 1990a:39, 1990b; Villa 1982:282). The presence of patina may also inform the analyst about technological variables: rocks exhibiting qualities which are preferred for knapping (Gillespie et al. 2004:626; Hiscock 1985:93; Villa 1982:282). Very few artefacts in the three analysed sites of the CQH were found to exhibit weathering (0.7%, N = 18) and as such a detailed analysis was not warranted. The artefacts displaying weathering modification may indicate recycling or scavenging of older artefacts (Hiscock 1985, 1988a).

**Excavation and Curation Effects**

Analysts must also consider the possible biasing factors already present in the collection as a result of excavation, collection and curation. Two of the main taphonomic biases potentially affecting the lithic assemblages from the CQH were loss of data due to large sieve sizes, and the alteration to artefacts through poor curation of the assemblage. Although Beaton applied consistent collection strategies to the lithic components of the three sites, attempting to retain the majority of the lithic assemblage during excavation and analysis, a 3 mm sieve was used to sieve the assemblages. Therefore a portion of smaller lithic specimens was probably lost through the sieves. Beaton placed “implements” in individual bags, while material identified as “waste” was placed together in a larger bag. As a result, the extent of modification of the marginal surfaces of “waste” artefacts due to point contacts in high density lithic assemblages, like those in bags, was unable to be quantified.
Lithic Taphonomy: Analytic Methods

Analysis of Microdebitage

A nested screening technique commonly used in sediment grain size analysis was employed in this analysis to separate fine debitage from sediment by size (Ahler 1989; Healan 1995:691; Stahle and Dunn 1982). The sediment sample was spread over a light box and viewed with a microscope, the frequency of microdebitage flakes was obtained per size fraction, and estimates of density were obtained by dividing the number of specimens by the volume of the column sample (Healan 1995:691; Metcalfe and Heath 1990:786). Microdebitage from the -2 to 0.5 \( \phi \) sediment fractions was analysed, as studies have indicated that the identification of microdebitage decreases with sieve size fractions smaller than 0.25-0.5 mm (Hiscock 1988b:201-204). As microdebitage may also be created as a result of trampling, clearly defined attributes were used to distinguish human small flake production as a result of human knapping from taphonomic processes (Akoshima 1987; Hiscock and Mitchell 1993:30). In this analysis microdebitage flakes with ringcracks were used to indicate human knapping or retouch, while those with bending initiations were probably created from damage to the margins of artefacts (edge damage) due to trampling in the deposits (Boot 1987, Mitchell 1988).

Fluvial Correlates

As there is not always an obvious correlation between fluvial processes and assemblage content and structure (Bowers et al. 1983; Schick 1987), multiple lines of evidence were used to investigate the extent of fluvial modification of the Cathedral Cave lithic assemblage.

Analysts have identified several correlates of fluvial modification of lithic assemblages, including grain size of sediment enclosing lithic specimens, estimations of the velocity, and transport potential of the currents across the archaeological site (Lindholm 1987; Pettijohn et al. 1987; Petraglia 1987, 1994; Petraglia and Potts 1994; Reineck and Singh 1986; Shackley 1974:501). The adherence of fluvial sediment matrix on lithic specimens is particularly informative as it indicates wetting and drying of fluvially deposited clay-rich sediments (Schick 1987:95).

Dimensional data is also used to investigate patterning in the lithic assemblage that could result from fluvial deposition or winnowing (Petraglia and Nash 1987; Petraglia and Potts
1994; Schick 1987). Experimental data from fluvial winnowing trials indicates that the weight of specimens can be a useful indicator as small flakes (5-10 mm in length) are particularly vulnerable to winnowing and removal (Petraglia and Pots 1994; Schick 1987; Stein 1993). To further assess sorting, the shape of specimens (using length, width and thickness), and settling times were analysed to investigate water velocity and potential for fluvial winnowing (Martin 1999; Petraglia 1987; Petraglia and Potts 1994; Reineck and Singh 1986; Shackley 1972, 1974:501). In addition, experimental research indicates that artefacts may display surface modifications caused by fluvial transport. Relevant correlates defined from overseas experimental research included abrasion, chipped edges, ridge grinding, striations, stress cracks, rounding, percussion craters and small cracks (Harding et al. 1983; Schick 1986, 1987, 1992; Schick et al. 1989; Schnurrenberger and Bryan 1985; Shackley 1972, 1974, 1978). Evidence of changes in vertical and spatial patterning of lithic objects is also an important line of evidence (Petraglia and Potts 1994; Shackley 1974, 1978).

Transverse Snaps

Artefacts can be broken in manufacture or in occupation as a result of taphonomic processes, and as such, it was essential to differentiate between the origins of the break and equate break types with taphonomic processes to define the formation of the assemblage (Hiscock 1985:87).

In general, snaps along the transverse axis of the artefact are usually created as a result of trampling, while snaps along the longitudinal axis of the specimen are created during manufacture. However frequencies of snaps can be affected by a number of specimen attributes including artefact morphology, raw material type, thermal alteration and sediment rate and depth (Cotterell and Kamminga 1987; Hiscock 1985; Hiscock and Walters ND; McBryde 1984:245; Mitchell 1988).

Hiscock’s and Walter’s (ND, see also Boot 1987) experiments indicate that flake morphology is an important variable affecting the likelihood of flakes to snap in trampling. They found short thick flakes are less likely to snap during trampling than long thin flakes. Flake morphology was assessed by measuring four size attributes, including length, width, platform width and platform thickness (Hiscock 1986; Macgreggor 2001; Mitchell 1988:50-51). Variation in the platform thickness and relative thickness of flakes was analysed to determine if change in flake morphology was responsible for change in transverse snap
frequency (Mitchell 1988:52). Given that both heating and raw material can affect the susceptibility of artefacts to transverse snapping, the analyses carefully controlled for the effects of these factors.

Following Hiscock (1985:89, 1988a), sedimentation rates derived from age-depth curves were used to investigate the impact of sedimentation rate on transverse snapping. Transverse snapping of flakes occurs when people stand on flakes lying flat on the ground surface. If sediment rate is related to increased transverse snapping, then the rate of flake breakage should be inversely related to the rate of sediment accumulation (Hiscock 1985:89). In principle, the slower the sedimentation rate the longer flakes lie in the taphonomically active zone and the more chance they have to be snapped (Hiscock 1985).

**Edge Damage**

The frequency of edge damage on flakes was used as another indicator of the intensity to which an assemblage has been subjected to trampling (Hall and Love 1985:77; Mitchell 1988). However, the likely origins of edge damage must be identified (Boot 1987; Flenniken and Hargarty 1979; Gifford-Gonzalez et al. 1985; Kamminga 1975; McBrearty 1996:109). While edge damage is usually considered to derive from post depositional trampling, edge damage may also result from several processes including tool manufacture and maintenance, tool use, and geological or other non cultural flaking processes (Flenniken and Hargarty 1979:208; Hall and Love 1985:77; Levi Sala 1986; McBrearty et al. 1998:106; Shea and Klenck 1993).

The presence or absence of edge damage was measured on flakes, flaked pieces and retouched flakes at these sites. Edge damage was identified as macroscopic flake scars extending on, or deriving from the ventral surface (Mitchell 1988). These must be distinguished from retouch, where flakes are removed from the ventral surface of the flake with an indenter (Mitchell 1988). Experiments indicate that flake scars derived from retouching are usually longer and larger than those produced by edge damage, and although retouch like damage has been identified in a range of recent experiments (Gifford-Gonzalez et al. 1985), this seems to occur with limited frequency. Flake scars on or extending from the ventral surface, displaying a ringcrack and longer than 3 mm were identified as retouch in this analysis (after Mitchell 1988).
As with transverse snapping, several other factors must be controlled when using edge damage as an indicator of trampling. These include sedimentation rates, which may be inversely correlated with edge damage frequency (since the longer a stone remains on the surface or near to it, the greater chances for edge damage to occur), flake morphology, edge angle, raw material (Burgess and Kvanme 1978; Hall and Love 1985:77; Mitchell 1988) and thermal alteration (Hiscock 1985). The angle of the edge of the flake will influence the frequency of damage in the assemblage. Flakes with acute angles between their ventral and dorsal surfaces are damaged more frequently than artefacts with obtuse angles. Edge angle was measured to determine whether change in flake morphology was responsible for changes in the frequency of edge damage on flakes (Mitchell 1988; Tringham et al. 1974:180). The range of raw materials in the region was quite variable, and has the potential to be a significant additional factor in artefact breakage. If edge damage occurred from attrition in the deposit, it would be expected that edge damage would be most frequent on broken flakes, as the mechanisms that break flakes could also damage their margins. If this was not the case then it was possible that flakes were damaged prior to discard, and can be used to indicate intensive stone working activities in certain periods of site formation (Hiscock 1988b:223; Mitchell 1988).

Edge damage caused by human use was investigated to determine whether flake use was an important cause of edge damage. If artefact use was a significant factor in the production of edge damage in these assemblages, then the frequency of edge damage on complete flakes should be equal to, or higher than the frequency of edge damage on transversely snapped flakes (Hiscock 1988b:223; Mitchell 1988:55). Striations on flake scars were used as an indicator of post depositional alteration as they occurred sometime after reduction (Gillespie et al. 2004:628).

**Vertical Movement**

Several analytic techniques were applied to investigate the extent of vertical movement of lithic artefacts and time averaging of assemblages as a result of trampling. These included analysis of the frequency of artefact distribution with depth from the surface, and the distribution of artefact weights and size with depth below the surface (Peacock and Fant 2002). As indicated by Cahen and Moyersons (1977), Gifford et al. (1985), and Villa and Courtin (1983:270), sedimentation rates and sediment bulk density were also important variables in artefact movement. In principle, weathering rates on artefacts may tell us about movement (see Hiscock 1988b for example) however, very low frequencies of weathered
artefacts were identified in the sites. Conjoining was not performed in this analysis due to time constraints and the large numbers of specimens in the three sites.

Thermal Alteration

Artefacts were examined for direct evidence of thermal modification, including cracks, fractures, pits, potlids, colour change, and lustre or glossy surfaces. Although cracks, fractures and potlids are easily identified, lustre and colour changes can be more difficult to identify. Lustre can only be recognised in comparison to a duller remnant surface (Crabtree 1972, Crabtree and Butler 1964). Greasy textures on flaked surfaces are the most distinctive change visible to the naked eye, however only a small percentage of flakes may have this feature (Domanski and Webb 1992:602). Thermally altered rocks may also exhibit a darkening of colour. Common colour changes that have been identified include a change from yellow brown to dark red; however darker coloured raw materials may show little change. Generally, colour differences can be difficult to identify as they vary with rock type as they vary with the water content and iron content of the rock (Domanski and Webb 1992:602; Flenniken and White 1983; Rowney and White 1997).

Research has indicated that lustre and colour change can occur at temperatures below that which are required to alter the fracturing properties of rock (Purdy 1974; Purdy and Brooks 1971). High numbers of specimens with thermal modification can be the result of a number of factors, including the increased use of fire, and increased quantities of stone material on the surface of the site at particular dated periods (Hiscock 1990a).

The rate of sedimentation is also an important determinant of the frequency of thermal alteration within these assemblages. Sediment rate may be inversely correlated with the rate of thermal alteration, since the longer a stone remains on the surface or near to it, the greater the chance that thermal alteration will occur (Hiscock 1985; Mitchell 1988; Stiner et al. 1995).

Weathering

The maximum weathering stage of lithic artefacts was coded as unpatinated, lightly patinated and heavily patinated (Hiscock 1988a, 1990a). However relatively few specimens exhibited weathering modification, due to the relatively short burial times in the CQH sites (refer Hiscock 1985; 1988a). Thus, weathering was not considered a major taphonomic
process increasing specimen fracture (Hiscock 1985:92), affecting the identification of humanly knapped specimens (Hiscock 1990a), or affecting the identification of taphonomic processes on specimens (sandblasting, heating).

Specimen Attributes

Analysis of the technological attributes of the assemblage was not a part of the analysis performed here. However, in order to reliably and consistently investigate causes and interactions of taphonomic and technological attributes on specimens, measurements required as part of the taphonomic analysis were taken in accordance with those commonly taken in technological analyses (Clarkson 2002; Cotterell and Kamminga 1987; Crabtree 1972:4-5; Hiscock 1984, 1986, 1988a, 1989:25-26; Shott 1989, 1994, 2000; Sullivan and Rosen 1985). These attributes included flake length, width, thickness and weight, raw material, artefact type (flake, core, retouched flake, flaked piece and non-diagnostic), flake termination, completeness and edge angle. Platform variables included platform width, thickness, platform type, angle and presence/absence of overhang removal (see Figure 5-3 and Figure 5-4), and the percent of cortex remaining (Hiscock 1988b). Contextual data (site, pit, level, Queensland Museum Accession Number, Beaton number, Beaton classification) was also “collected”. Lithic surface alteration features were identified by scanning ventral and dorsal surfaces and marginal edges under an x10 hand lens. The complete list of attributes and their definitions is summarised in Appendix Table A-14.
Chapter 6: Macrozamia Moreii Taphonomy and Analysis

In attempting to evaluate an archaeo-macrobotanical collection, several questions of archaeological site formation and analysis must be considered (Rossen et al. 1996:391).

There is little doubt that (taphonomic) principles can be applied to any plant matter which requires careful examination to establish the source of the plant material but also the extent of any physical changes that have affected it over time from death to recovery (Mountain 1999:vii).

Introduction

Like other lines of evidence, archaeobotanical remains do not provide a straightforward, pristine record of human plant use as they are often incorporated into archaeological sites by a range of cultural and non-cultural processes (Clarke 1988, 1999:83; Hansen 2001:401; Hather 1994:52; Ladd 1988:2; Murphy 1992:9; Miksicek 1987; Nelson 1992:240; Pennington and Weber 2004; Spicer 1991:72; Rossen et al. 1996:405). An extensive literature review of Macrozamia reproduction cycles and general ecology was undertaken to shed light on the range of taphonomic processes operating on Macrozamia seeds on their journey from the plant to an archaeological deposit.

The Macrozamia specimens from the three CQH archaeological sites were analysed to investigate the possible taphonomic agents involved in their transport, deposition and transformation. Prior to this analysis none of the Macrozamia remains from these sites had been taphonomically assessed. Before discussing aspects of Macrozamia taphonomy, a brief introduction to the genera is presented. Then the chapter discusses the major taphonomic processes that have shaped the assemblage, including 1) transport, deposition and accumulation by wind and water, animals and humans, 2) bioturbation disturbance by animals, plants and humans, 3) fluvial movement, 4) burial processes including pH, and 5) overburden weight and compaction. The second half of this chapter outlines the methods used to analyse the Macrozamia specimens in these sites. The context and limitation of Beaton's (1977, 1991a, 1991b) excavation techniques, quantification and methods concerning further analysis are outlined.
Background to Macrozamia Ecology

There are three families of cycads around the world: Family Cycadaceae (Genus Cycas), Family Stangeriaceae (Genera Bowenia and Stangeria), and Family Zamiaceae (Genera Certatzamia, Chigua, Dioon, Encephalartos, Leipdozamia, Macrozamia, Microcycas and Zamia) (Butt 1985; Hill and Osborne 2001:3; Jones 1994). Australia has three endemic genera: Macrozamia (14 species) (Figure 6-2), Lepidozamia (two species) and Bowenia (two species) and a number of non-endemic cycad species (Hill 2003:20, Figure 6-1). M. moreii is one species within the genera of Macrozamia in Australia. M. moreii plants are endemic to the CQH, and are densely distributed throughout the dry schlerophyll forests, the escarpment of rocky gorges and in coarse sand from alluvial deposits (Jones 1994:87, 249; Low 1991:138). Although these plants are exceptionally long lived they take a long time to grow: an estimated 2 m in 100 years (Jones 1994:251).

Macrozamia seeds have a complicated developmental period and survive for a long time in the environment, exposing the seeds to a wide range of taphonomic processes. Plant reproduction proceeds by the production of seeds, which are attached to a stroboli (cone) (Figure 6-3). The Macrozamia seed is composed of the fleshy outer layer (sarcotesta) which covers a hard stony shell (sclerotesta) inside of which is a starchy kernel containing the embryo (Figure 6-5). The term "seed" is used in a general sense although in botanical terms these are fruit. The woody seed coat is called an endocarp, and the inner kernel more correctly termed an ovule (Jones 1994).

Plants begin to produce their first reproductive cones at c. 50 yrs of age (Jones 1994). Female plants produce large viable stroboli, positioned around the leaf crown. The time taken for female plants to produce stroboli from cone initiation to break up varies by genera and species, ranging between 6-18 months or more (Jones 1994; Hall et al. 2004). The seeds are arranged around the central axis of the stroboli and are held in place by sporophylls (Jones 1994:44; Low 1991:138). M. moreii typically contains 300 seeds per stroboli (Beaton 1981; Rolf Kyburz pers. com; pers. obs). The numbers of seeds and stroboli on plants depend on environmental conditions, the maturity of the plant and the numbers of stroboli on the plant (Cronin 1989:122; Jones 1994:15, 45, Chapter 11). Seeds remain on the stroboli for up to a year, the outer flesh (sarcotesta) ripening and changing colour from green to the characteristic yellow-red. Several months after this the mature female cones begin to deteriorate from the apex downwards (Figure 6-4), with sporophylls falling from the central axis with semi mature seeds attached. The seeds of most Macrozamia species cannot germinate immediately on maturity. This is because the embryo has an after ripening period,
the length of which varies with the species, in *M. moreii* it is eight months (Jones 1994:15). The production of cones places a considerable drain on the plant’s storage reserves, and thus frequency of stroboli production varies between species. *M. moreii* generally produces 2 cones per plant every 2-3 years (Jones 1994).

**Macrozamia Taphonomy Depositional Processes**

*Gravity*

Seed dispersal due to gravity (the natural break up of the stroboli, Figure 6-3 and Figure 6-4) was an important factor to consider in Cathedral Cave as a plant currently grows within the confines of the shelter. A study of the average dispersal of seeds by natural windfall was conducted by Burbridge and Whelan (1982:63). Unopened stroboli of two *Macrozamia reidlei* were caged to protect against animal predation in order to accurately assess seed dispersal. They found that caged seeds came to rest within a 40 cm radius from the base of the parent plant \(N = 83, 332 \text{ seeds per m}^2\). Watkinson and Powell (1997:341) also found that in tall *Cycas armstrongii* plants, seed dispersal was frequently restricted to less than 1 m away from parent plants. Farrera (2004:307) and Vovides (1990) found that seeds were dispersed on steep slopes. Studies by myself in the Canberra Botanical Gardens and the Royal Sydney Botanical Gardens indicate that the height of the stroboli above the ground surface is not a factor in windfall seed dispersal distances of *M. moreii*, as the majority of seeds of *M. moreii* regularly fell within 1 m of the parent plant during break up of the stroboli (Figure 6-6, Appendix Table A-16).

*Wind*

Wind is not considered to be a major factor resulting in seed deposition in the archaeological sites of the CQH. This is based on Burbridge and Whelan’s study in which they noted wind transport to be negligible (1982:65). The large size and weight of most Macrozamia seeds makes it unlikely that long distance dispersal occurs without the aid of animal or human vectors (Burbridge and Whelan 1982:65).

*Floods*

Storms can remove individual leaves or multiple seeds from plants, and when coupled with flooding, may lead to significant quantities of plant products being deposited (Hansen 94).
Geomorphological studies indicate that floodwaters regularly transport a range of botanical items including leaves (Boyd 1990; Kowalewski 1997), small woody debris (Baudrick and Grant 2001; Baudrick et al. 1997; Boyd 1990; Macdonald and Jefferson 1985:237), charcoal and other charred material (Alexander et al. 1999:105; Archer 1974a; Baker et al. 1993, 1985; Spicer 1991:95; Vaughan and Nichols 1995). Fluvial events can also modify macrobotanical assemblages through erosion, redistribution and redeposition of pre-existing accumulations of natural and cultural plant materials, and re-deposit a mixture of organic materials carried in debris flow (Alexander et al. 1999:105; Archer 1974a; Balme and Beck 2002:164; Hansen 2001:425). Cycad seeds have positive buoyancy and are believed to have colonised the Pacific by oceanic dispersal (Deghan and Yuen 1983; Hill 1984, 1998; Keppel 2001). Therefore assessing the potential allochthonous nature of the *M. moreii* assemblage was required to investigate the ease of transportation and deposition of seeds into Cathedral Cave (Hansen 2001:407).

**Settling experiments**

A number of experiments were performed in order to explore fluvial deposition and transport, and distinguishing fluvial from humanly deposited *Macrozamia* remains at Cathedral Cave. Transport potential was assessed by estimating a specimen’s equivalence to quartz grains deposited in fluvial systems (Behrensmeyer 1975) (Table 6-1). Several samples of *M. moreii* seeds were selected for this experiment: 1) those which had been humanly fractured into longitudinal and transverse specimens (Chapter 7), 2) complete uncarbonised and carbonised specimens, 3) complete specimens with and without sarcotesta, 4) and carbonised and uncarbonised complete and fractured specimens.

A large trough of 40 cm depth was filled with water. Specimens were steadied 1 cm under the top of the water level and released in various orientations (concave up and concave down) at the top of the container. The time taken for each specimen’s journey to the bottom of the container (settling time) was timed with a stopwatch. In order to take into account the inherent inaccuracies of hand-timing, each fragment was released and timed five times and the average settling time used to determine grain size equivalence. The settling times of specimens were tested in both their dry and saturated states. Specimens were saturated by leaving them immersed in water for 24 hours prior to experimentation.

The results indicate that all *Macrozamia* remains are highly vulnerable to movement by water (Appendix Table A-17, Appendix Table A-18). Both complete *Macrozamia* specimens
with and without sarcotesta, and burnt and unburnt specimens remained buoyant after 24 hours in water. The finding that complete Macrozamia specimens float is consistent with the results obtained in experimental tests of buoyancy in Cycas sp. by Dehgan and Yuen (1983:412). They suggest that buoyancy in Cycas sp. may be attributed to the air space created by the shrinkage and separation of the kernel (endosperm) together with the tynpanum of the sclerotesta (Dehgan and Yuen 1983:412). In addition, parts of the sporophyll and cone also floated for more than 24 hours. Complete kernels that were carbonised also floated, however uncarbonised specimens floated until the kernel absorbed water, when the kernel fragmented into several pieces. Carbonised fragments of all specimen shapes also floated for more than 24 hours. This indicates that these fragment types will be moved by water, or be incorporated into archaeological sites in high stage flood events.

All uncarbonised fractured specimens sank, including longitudinal, transverse and triangular pieces, common in archaeological sites. The average settling times and average velocities per cm² varied by specimen shape, as shape variations created differences in the path specimens took through the water (see also Martin 1999:38). The presence of air bubbles between the water surface and the sclerotesta also created differences in settling paths (see Allen 1984 and Brenchley and Newall 1970 for similar studies in bivalve shells). Saturation changed the settling times of uncarbonised fractured specimens. Dry specimens had a quartz equivalence of silts and clay (6.0 to 14.0 φ) and saturated specimens had a quartz equivalence of fine sands (2.35 φ) and very fine sands (3.52 φ) (Pettijohn et al.1987). The saturated fragments had on average twice the settling velocity of unsaturated specimens, but would be readily moved by floodwaters (see Table 6-2 and Table 6-3). Therefore fractured burnt specimens could have been brought into and removed from Cathedral Cave on the floatation load, and uncarbonised fragments could have been deposited or reworked in the saltation load at the sediment water interface during flood events at Cathedral Cave (Chapter 8).

Animal Dispersal and Transport of Macrozamia Seeds

Although the seeds are large and heavy, several animals are known to be involved in transporting seeds away from parent plants (Burbage and Whelan 1982; Moore 1999) (Appendix Table A-20). The characteristics of the seeds of M. moreii aid their transportation by animal vectors. The outer fleshy layer is brightly coloured and acts as a food attractor, providing a nutritionally valuable edible starchy food reward (Jones 1998; Moore 1999, see also Renner 2003). This aids local dispersal across land. If the flesh has rotted off or been
eaten off by another animal, then the kernel inside the seed provides a starchy reward for other predators (Dehgan and Yuen 1983:412; Jones 1998:60). Seeds can be predated throughout the year, but are important food resources in the lean winter months, which also increases seed dispersal and predation (Ballardie and Whelan 1986:103).

Several studies around the world have identified a number of animals which transport, predate and deposit seeds in cycad populations. These include possums (*T. vulpecula*) (Ballardie and Whelan 1986; Burbage and Whelan 1982; Hill 1984; Kennedy 1993; Tang 1990; Wakinson and Powell 1997:347), rodents (Sanchez-Tinoco and Engleman 2004:36; Tang 1990; Vorster 1995:383), fruit bats (*Pteropus* sp.), (Bauman and Yokohama 1978:73; Jones 1994:62; Kennedy 1993; van der Pijl 1957; Vorster 1995:383), Macropods, including the grey kangaroo (*M. fuliginosus*) (Kennedy 1993) and the western brush wallaby (*M. irma*), and birds (Carter 1923; Hill and Osborne 2001:5; Loaring 1952; Sargent 1928; Stranger and Stranger 1970; Sedgwick 1952; Tang 1990; Vorster 1995:383). The native cat (*Dasurus geoffroyi*), bandicoots (*I. macrourus* and *I. obseleus*) and dingoes (*C. lupus dingo*) (Hill 1984) are also vectors in Macrozamia communities.

The main animal vectors involved in the CQH have been identified as 1) birds, 2) rodents, and 3) possums. These animals may eat sarcotesta from seeds attached to cones or break up cones to access seeds, and may carry whole seeds and sporophylls for some distance before stopping to eat the sarcotesta and also the kernel (Burbage and Whelan 1982:65; Jones 1994; Parton 1952). They may also be responsible for depositing seeds in the three archaeological sites, mimicking human activity areas within relatively small time scales. Animal dispersal may account for the general dispersal of seeds, and can result also in cycad plants which may be found isolated and uphill from main populations (Jones 1994:61; Kennedy 1993).

**Birds**

Various species of birds have been identified as vectors of Macrozamia seeds. Cassowaries, emus and hornbills (*Bucerotidae* sp.) predate African *Encephalartos* sp. (Hill and Osborne 2001:5; Tang 1990; Vorster 1995:383), while crows (*Corvidae* sp.), thrushes and sacred ibis (*Threskiornis aethiopica*) (pers. obs.) have been observed dispersing *Cycas revoluta* seeds (Vorster 1995:383). Several studies from across Australia have also documented western rosellas (*Platycerus icterotis*), white tailed black cockatoos (*Calyptorhynchus baudinii*), ravens (*Corvus corone*), emus (*Dromaius novaehollandiae*), pigeons (*Phaps chalcoptera*), silvereyes (*Zosterops lateralis*), cassowaries and bower birds feeding and
dispersing seeds of various *Macrozamia* sp. (Carter 1923; Loaring 1952; Sargent 1928; Sedgwick 1952; Stranger and Stranger 1970).

Larger birds including crows, cassowaries and emus can be effective dispersal agents, swallowing the seed whole and voiding it later without the digested sarcotesta (Burbage and Whelan 1982). Identification guides can be used to identify damage to the flesh of seeds (Department of Natural Resources and Environment 2002) left by birds or flying foxes. Ultimately however, there was no positive evidence that birds were an important dispersal, depositional and fracture agent with seeds in the archaeological sites of the CQH.

**Rodents**

Rodents are perhaps the most important taphonomic agents in *Macrozamia* communities in Australia (Jones 1994:62), and were identified as important agents in the CQH. Because of this, an extensive literature review concerned rodent activities on seeds in *Macrozamia* populations. Rodents typically feed on the fleshy layer of the seed when it is present, as well as the contents of the seed (Ballardie and Whelan 1986:104). Overseas studies of rodent predation of cycad populations indicate that seeds can form a major part of the diet of both rats and mice in natural conditions. A study of two populations of *Zamia amblyphyllidia* indicated that between 30-38% of seeds were dispersed or eaten by rodents (Negron-Ortiz et al. 1996:609). A study of *Ceratozamia mexicana* indicated that 3% of the population was dispersed and partially eaten by rodents (Farrera 2004:307; Sanchez-Tinoco and Engleman 2004:35). Similarly, seeds and cones of *Dioon edule* were dispersed by rodents (Farrera 2004; Vovides 1990:1539). The hoarding of cycad seeds in small caverns and crevices in and around rocky outcrops by the rodent *Peromyscus* sp. has also been observed (Vovides 1990:1542). Seeds forgotten by rodents may germinate and contribute to the spatial distribution of the species (Sanchez-Tinoco and Engleman 2004:35; Vovides 1990:1542).

Several studies of rodent predation and transport of seeds from cycad populations are available in Australia. A study of seed predation in a masting Macrozamia population (defined as the synchronous intermittent production of large seed crops in perennial plants; Kelly and Sork 2002:427) and a non-masting population of *M. communis* indicated that rats more highly predate seeds in the masting plot than the non-masting plot. Approximately 19% of seeds in the masting population displayed eaten kernels, compared with 2% of seeds in the non-masting population (Ballardie and Whelan 1986:103) (Table 6-4). The number of seeds which displayed toothmarks on the outside flesh of the seed and gnawing through to
the woody layer into the kernel and embryo was 10 times greater in the masting population than the non-masting population (Ballardie and Whelan 1986:104). Rodents may attack the immature cones when the sarcotesta begins to show colour (Begg and Dunlop 1980:65; Jones 1994:63) or may attack very aged seeds, which have shrunken hard kernels within a weathered coat (Jones 1994).

Rats are attracted to populations with an abundance of seeds (Ballardie and Whelan 1986:104; Schnurr et al. 2002). Rodents prefer to gnaw seeds beneath parent plants, or collect seeds from open areas, and transport them to secure locations near hollow logs and rock crevices, in fissures, small overhangs, or under dense plant cover, where they eat in safety from being seen by a predator (termed security eating), especially if seeds are tough or hard to open like Macrozamia (Ballardie and Whelan 1986:101; Begg and Dunlop 1980:68).

Rats can also sequester seeds into secure areas within rockshelter and archaeological sites. The movement of seeds by rodents to and within cave sites in schlerophyll environments was investigated by Murphy (1992). Thirty whole marked M. diplomeria seeds with the outer flesh removed were placed on the floor of a rockshelter. Of these, 24 were carried 1.5 m away and up 0.5 m in height into a small crevice at the back of the shelter and gnawed open to eat the kernel (Colvill 1995:16; Murphy 1992:91). Given the above, it is unsurprising that rodent toothmarks have been identified on Macrozamia assemblages in archaeological sites. Beck identified that seeds from two rockshelter sites with archaeological deposits in New South Wales (Bombaderry Creek and Capertee 3) had been gnawed (Beck 1989:46), while Murphy (1992:93) identified 700 Macrozamia seed fragments which contained rodent toothmarks at Kawambarai Cave.

The rodent transport, collection and predation of Macrozamia seeds was also monitored during the experimental programme (see Chapter 7) in the School of Archaeology and Anthropology, ANU. A sample of M. moreii seeds were in short term storage in a cardboard box, 1 m above ground level. After one month of storage, over one weekend “Sparky” (Rattus fuscipes) gnawed a large hole in the box (9 cm long and 12 cm wide). Two seeds had been transported 2 m to the back corner of the lab under the bookshelf. This position was the closest sheltered position and does not reflect the distance this species is carried in the wild (as above). Evidence for gnawing consisted of the removal of the sarcotesta from the shell and a fine powder of sarcotesta on the carpet. Over the course of one month, Sparky visited the lab on weekends and at nights, removed between one and four nuts at a time from the
box, and transported them under a bookshelf where the sarcotesta was removed and gnawed into the shell, eating the kernel. A total of 22 nuts were collected in this way before occupational health and safety put an end to my actualistic study. The sample had a mean weight of 23.78 g (after the removal of the sarcotesta) (see Table 6-5).

Samples of rodent gnawed *Macrozamia* sp. and *Cycas* sp. obtained from commercial suppliers and those gnawed by Sparky (see below) were analysed for rodent toothmarks. Size characteristics were analysed to investigate if there were limits to rodent dispersal of these species. The results indicate that rodents are not inhibited by the weight of the seed, selecting seeds weighing between 3.21-35.71 g. Similarly, rodents are uninhibited by the size of seeds, taking seeds between 20.4-56.5 mm. The average seed size of most Australian *Macrozamia* sp. ranges between 27.0-45.0 mm length and 20.0-55.0 mm width (Table 6-6, Figure 6-7), and fall well within the ranges of the actualistic and commercially obtained specimens that exhibited rodent toothmarks. Dispersal does not seem to be affected by the presence of the flesh (Burbage and Whelan 1982:63). This indicates that rodents are likely to be an effective transport and fracture agent in all *Macrozamia* communities (see also Jones 1994). Transport away from the parent plant is beneficial to the parent plant by increasing the chances of survival from reduced competition (Jones 1994:60; Ornduff 1985).

**Possums**

Possums are highly effective dispersal and predation agents on *Macrozamia* seeds, feeding on the outer fleshy integument without breaking through to the stony layer (Ballardie and Whelan 1986; Burbage and Whelan 1982). Understanding the feeding habits of possums in *Macrozamia* communities helps the analyst to understand taphonomic signatures indicated by gnawed seeds in archaeological sites. Possums break the stroboli apart to collect the newly matured seeds (Ballardie and Whelan 1986:101), and have even been reported to dig up and carry off seeds planted in pots (Hill 1984:10). Burbage and Whelan (1982) found that possums could disperse seeds at least 24 m from the parent plant to their eating position in a tree and frequently left seeds in the fork of a tree 3 m above the ground (Burbage and Whelan 1982:63). In their study of animal transport of seeds from six uncaged stroboli, only 28% of the seeds remained within the first 50 cm, while 6% reached 5 m or more, and 1.5% reached 10 m from the parent (Burbidge and Whelan 1982:64). All seeds had the flesh removed and showed signs of toothmarks on the stony shell (Burbage and Whelan 1982:64). Because possums were considered to be a potential taphonomic agent at these sites, criteria were developed through which to identify and distinguish the toothmarks of possums and
rodents (Appendix Figure A-1 to A4). Ultimately, there was no evidence of possum toothmarks in the archaeological Macrozamia assemblages of the CQH.

Seed Dispersal and Macrozamia Population Density

Burbage and Whelan (1982) also identify several important factors which may also affect animal seed dispersal in Macrozamia communities. They indicate that seed transport distances in isolated plant communities may be different when compared to dense clumps of Macrozamia plants. In patchy populations with few cones, or when coning is at a low frequency, seed dispersal occurs by animals fighting for feeding rights to disintegrating cones (Jones 1994). Dispersal rates may be increased in high-density Macrozamia populations, due to the increased density of seed cones, which increases vector density but reduces animal feeding competition. Ballardie and Whelan also propose that the number of stroboli in an environment at the same time (e.g., high rainfall, see Chapter 11) might also affect seed dispersal, hypothesising that more cones may lead to increased dispersal (1982:65).

Seed Dispersal and Animal Territoriality

The dispersal of seeds in populations may also be affected by the patterns of feeding behaviour and territoriality of possums in Macrozamia populations. Possums are territorial, and have large home ranges. In non-masting populations, possums may remove seeds to locations where they will not be disturbed by competitors while eating the fleshy coat, but this security feeding behaviour may not be necessary if a possum has access to a large seed bank in a masting population (Ballardie and Whelan 1986:103-4). Ballardie and Wheelan (1986) found that seeds with their sarcotesta removed by rats early in the season would not be further dispersed by possums (Ballardie and Whelan 1986:104). Burbage and Whelan concluded that the geographical distribution of the territorial range of Trichosurus sp. and several rodent species completely overlap that of Macrozamia, creating the potential for widespread local dispersal of the seeds (Burbidge and Whelan 1982:63).

Humans

Criteria have been proposed by several researchers in order to distinguish human and non-human (natural) deposition of plant remains in archaeological sites. These include the distance between the plant habitat(s) and the archaeological site (Clarke 1999:84), the
presence of large quantities of one taxon (Evans and O'Connor 1999:138; Ladd 1988), the size of plant remains (Ladd 1988:14), ethnographic documentation of use (Ladd 1988), carbonisation of the plant remains (Ladd 1988:14), the “fresh” appearance of plant remains and plants which require processing prior to consumption (Clarke 1999:83; Ladd 1988:14), associations with other items (e.g., grindstones) (Ladd 1988:14) and specific areas of plant deposition (Balme and Beck 2002:158). However because of a range of taphonomic ambiguities, very few of these criteria may be considered to indicate the human use of Macrozamia.

The distance of Macrozamia plants from an archaeological site, and the quantities of seeds in the CQH archaeological sites are not useful criteria to identify depositional agents. This is because several animal vectors can deposit Macrozamia seeds 1) significant distances from communities and into protected areas within archaeological sites, 2) can accumulate large quantities of one taxon in archaeological sites, and 3) and the size of seeds do not inhibit their transport. Burning does not indicate the sole human use of seeds as 1) carbonisation may occur when seeds are on the ground surface from natural or humanly lit fires, and 2) carbonisation stages may reflect incidental burning of plant remains in surface deposits or the deliberate or accidental discard into hearths. Also, the age of the specimens is not a useful indicator as both aged and fresh Macrozamia remains are transported and eaten by animals and humans. Associations of items used to process plant remains are very rare in most Australian archaeological contexts and specific areas of deposition are often difficult to identify. Even diversity or association of different plant parts (including sporophylls, seeds and kernels) are not direct indicators of human use of Macrozamia plants as these parts may become incorporated into archaeological sites by a range of separate taphonomic processes.

Evidence for the human use of Macrozamia seeds must rest on evidence for the human fracture of the shell (produced in the extraction of the edible kernel, which is used to make flat cakes or bread) (Beaton 1977; Beck 1985, 1990, 1993; Levitt 1981; Meehan and Jones 1977; Thompson 1938). An experimental research programme was undertaken to investigate specific cause:effect relationships of the human fracture of Macrozamia seeds. The experimental programme 1) identified patterns of fracture consistent with ethnographically documented methods of Macrozamia processing, 2) explored specimen variability caused by different fracture techniques, and 3) investigated specimen variability caused by different carbonisation extents. The experimental programme and results obtained are outlined in the following chapter.
Macrozamia Taphonomy Post Depositional Processes

Weathering

The weathering stages of Macrozamia seeds in an archaeological site also provide important information on human and animal collection strategies and environmental conditions at the time of collection. Macrozamia seeds in the CQH are regularly exposed to environmental extremes (Dick 1964). After the flesh of the *M. moreii* decays, the shell can be exposed to the natural elements up to two years or more, increasing fragility. Because of their long exposure time in the environment (from initial seed production to dissemination from the stroboli), transportation vectors and long after ripening periods, Macrozamia seeds may be significantly weakened by the time they are deposited in archaeological sites. Weakened structures may be more easily broken down by post depositional processes (Clarke 1999:84), especially when in a fractured state. The weathering of Macrozamia seeds is indicated by two features: a colour change in the seed from mid brown to grey-white, or the presence of small transverse splits in the sclerotesta (Levitt 1981:48).

Bioturbation

As discussed in Chapter 3, cattle, dogs and humans are potential bioturbation agents in the CQH archaeological sites and could have altered the distribution and preservation of botanical remains on the surface or within these sites. Trampling by humans and digging by animals may significantly alter the spatial and horizontal distribution of botanical remains, fracture specimens, incorporate other plant remains into the deposit, promote vertical movement and increase the rate of microbial breakdown through aeration of the deposit (Clarke 1988:131, 1999:85; Hansen 2001:416; Lenstromm and Hastorf 1992:207-8; Miksicek 1987; Murphy 1992; Nelson 1992:254; Wood and Johnston 1978). Lithic research suggests greater lateral movement of objects on hard sediments and greater vertical movement in loose sediments (Balme and Beck 2002:160). Site maintenance activities can also significantly alter the distribution and preservation potential of plant remains (Binford 1978; Schiffer 1976, 1987, 1988).

Burning

The highly lignified (woody) nature of the sclerotesta of the Macrozamia seed makes seeds extremely durable in the archaeological record. As discussed in the previous section, Macrozamia seeds are often carbonised as part of the cooking process. This aids the
preservation of the seed (Hansen 2001:405; Miksicek 1987; Nelson 1992:252; Pearsall 1989:229, 440; Spicer 1991:95), as carbonised seeds do not provide sustenance for microorganisms within the sediment (Beck et al. 1989:38; Evans and O’Connor 1999:138). Carbonised specimens are also resistant to decay as they are chemically inert as an elemental carbon (Ladd 1988:10). However differences in preservation potential may exist between carbonised seeds, and older weathered seeds which can be used “off the ground” and are not subjected to carbonisation during processing. Preservation and depositional bias is non-random, making it difficult to compare quantities of remains directly (Pearsall 1988). Methods to investigate biases in preservation due to burning and concomitant effects of pH are discussed in the second part of this chapter.

Micro-organisms

Botanical remains may be broken down by a variety of micro-organisms, including soil flora, microbes, bacteria and fungi (Begg and Dunlop 1980:69). A range of small insects and micro-organisms leave a range of diagnostic features (Figure 6-8) which can be used to indicate breakdown, and infer environmental conditions at the time of deposition. Fungal attack was observed to be a major taphonomic process in Macrozamia seeds in experimental trials, occurring during the germination of the seed, or after the breach of the shell, causing exposure and breakdown of the kernel. It is possible that fungal decay had begun in seeds brought to archaeological sites, as this process leaves no outward signs on the shell (pers. obs.) and cannot be used to differentiate human from animal transport, accumulation, dispersal or fracture of the Macrozamia seeds.

Weevils and borers

The major insects modifying the sarcotesta, sclerotesta and ovule of Macrozamia seeds is the Tranes weavel, Tranes lyterioides, which is an important pollination vector in the species (Jones 1994:57, 59). The presence of Tranes sp. related modification to the surface of Macrozamia seeds can provide important information concerning the timing of Macrozamia deposition in the site and information about the size of the population the seed was collected from as pollination vectors are density dependent (Jones 1994:62). These weevils live on the outer fleshy layer for up to 6 months of the seed age before turning into a beetle (Jones 1994:62). The grub stage leaves long curved deeply incised, smooth edged, wide grooves on the sclerotesta (Figure 6-9). In a sample of 2,000 M. moreii seeds obtained from a population in the CQH, approximately 1/3 of the quantity had this beetle in the flesh, most of the seeds 104
displaying incised lines or more subtle surface erosion of the sclerotesta. The other insect
known to modify Macrozamia seeds is the cycad seed borer, Antliarinus zamiae (Jones
1994:79), which bore holes from the sclerotesta into the kernel (Figure 6-10).

\textit{pH}

The pH of the sediment in these sites ranges from acidic to alkaline, resulting in different
preservation biases between the sites and between levels within sites in the region. Sites with
low pH limit the activity of biological agents which cause decay, Balme and Beck finding
that pH did not affect carbonised plant remains (2002:159, 164), however deposits with
medium or high pH provide conditions favourable to botanical decay. The relatively dry
environments of the archaeological sites in the highlands are likely to aid the preservation of
the seeds through desiccation (Hansen 2001:402; Hather 1994:54) and limit decay rate
preventing organisms from consuming organic material (Hather 1994:5; Ladd 1988:3), but
may increase the brittleness of the material through oxidation (Spicer 1991:77). The size,
density and surface characteristics of seeds may influence the decay rate, with small pieces
more susceptible to degradation by chemical and biological agents (Colvill 1995:17; Hather
is likely to aid preservation in highly acidic, poorly oxygenated environments of some layers
in these sites (Clarke 1999).

\textit{Compaction}

After burial, plant matter invariably undergoes some degree of alteration from compressive
forces of sediment overburden and or sediment compaction from trampling in high traffic
areas (Balme and Beck 2002:160). These processes may increase fracture and increase
reduction in specimen size. In some cases, these processes can create distortion in the
vertical plane of specimens, or create lateral expansion (Spicer 1991:88). Post depositional
compaction in sandy sediments occurs in high traffic areas and may be related to ceiling
height (Balme and Beck 2002). Compaction was considered a likely process at Cathedral
Cave due to overburden weight, but was not a factor in Rainbow or Wanderer’s Caves where
the sediment had low bulk density.
Excavation and Curation Taphonomy

Biases may be introduced at the recovery, sorting and laboratory stages in the analysis of a macrobotanical assemblage. These may substantially affect interpretation, and as such, these should be reviewed (Nelson 1992:240; Pearsall 1989; Popper and Hastorf 1988:6). Beaton collected most *M. moreii* seeds remaining on the 3 mm sieve and stated that some fragments were not collected (Beaton 1977, 1991a, 1991b). It is possible that smaller macrobotanical remains were not recovered using the 1/4 or 1/8 mesh sieves, as is the case with small faunal specimens and lithic artefacts (James 1997; Lenstromm and Hastorf 1992:205). The samples were not wet sieved or floated, avoiding increased fragmentation from these mechanisms, however travel and storage may have introduced biases into the recovered sample through loss or destruction to the remains over the last 30 years (Pearsall 1989:440). Care was taken in the analysis so as not to create further biases through fragmentation.

Macrozamia Taphonomy: Analytic Methods

Identification to Species

There are several species and subspecies of Macrozamia in the CQH (see Hill 1989a, 1989b, 1998, 2003; Jones 1994). Confirmation that the seeds in the CQH archaeological sites were *M. moreii* was required. A range of methods were used, including: 1) consideration of the distribution of species near the archaeological sites, 2) comparisons of the archaeological specimens and modern seed size data (Jones 1994), and 3) and a 1:1 comparison of morphological and anatomical characteristics between collected samples of fresh and weathered homologous plant parts, and the archaeological samples (Hather 1994:60; Johannsen 1988:149; Jones 1994). However, analysts should also be equated with heat induced changes to seed morphology in order to visualise the original appearance of the carbonised matter and any effects on identification to species (Helbaek 1963:210-211).

Identification of specimens to species level and anatomical portion can be difficult due to changes to seed morphology (shrinkage, distortion and cracking) as a result of carbonisation (Boardman and Jones 1990:1; Greig 1989:53; Gustaffson 2000:65; Hather 1994:52; Mangafa and Kostakis 1996; Pearsall 1989:440). Three samples of 20 *M. moreii* seeds were heated in the ANU’s School of Archaeology and Anthropology’s electric “Naber” furnace. The furnace was preheated and seeds and fragments that were created in experimental trials (refer Chapter 7) (with and without sarcotesta) were placed inside the furnace to generate
comparative samples of seeds at different carbonisation stages. Temperatures the nuts were likely to have been exposed to in archaeological conditions were ascertained from other experiments simulating hunter-gatherer campfires (Robins and Stock 1990). The length of time that specimens were roasted was derived from descriptions in ethnographic accounts. Specimens were heated to 200 °C and 400 °C, representing the approximate heat in ashes and in sediments directly beneath fires and replicates roasting of Macrozamia nuts, while samples at 600 °C represent the upper limits attained in campfires. The starting temperature and the finishing temperature remained constant for the duration of the experiment.

Macrozamia were not susceptible to thermally induced distortions in shape, perhaps as a result of the highly lignified (woody) structure of the seed (Hather 1994:54). Colour change were observed at the two different temperatures, with 200 °C resulting in a light to mid brown colour, and 400 °C resulting in carbonisation and a black colour. The kernels of specimens heated to 400 °C also became darker in colour and harder. Specimens heated to 600 °C displayed large semi circular cracks and small checking, with carbonised, hard and glassy kernels remaining within the shell.

Identification to species was limited in specimens smaller than 0.5 mm in width or length. Identification of the anatomical end of the seed (on which MNI was based, see below), was limited to the preservation of part of a diagnostic end, and size restrictions. The precision of identification was not limited by state of preservation and fortunately the specimens in the lower deposits, although transformed taphonomically, were identifiable to species and diagnostic ends.

Vector Identification Methods

As discussed above, rodents (rats and mice) were the main taphonomic agents operating in M. moreii in the CQH. Analysis of rodent traces on Macrozamia seeds when eating the flesh or the kernel may be identified by 1) toothmarks, 2) breaches to the shells, 3) gnawed areas of kernels, and 4) spatial distribution of gnawed specimens.

Rodents

Toothmarks of Rattus sp. (Figure 6-11, Figure 6-12) can be easily identified as they leave long, closely spaced linear parallel grooves and scratches around the body of the shell. These marks are often located transverse to the main longitudinal axis, and occur in overlapping
multiple sets, or singular sets (Jones 1994:61). The upper incisors, which hold the seed, leave short curved or circular marks on the shell, while the lower incisors leave long furrows opposite to these marks (Triggs 1996:226).

Rodent gnawing on a sample of nuts obtained from a commercial supplier and those obtained from “Sparky” (R. fuscipes) were analysed to understand patterns of gnawing behaviour and assess the potential for information to be derived from the archaeological record. The data (Table 6-7, Table 6-8, Table 6-9 and Table 6-10) indicate that the majority of gnaw marks occur on the body of the specimen, transverse to the longitudinal axis, and appear as spatially restricted parallel lines.

The analysis of the samples created by “Sparky” indicated that the area of the nut with toothmarks and their distribution may relate to the amount of sarcotesta remaining on the seed and the level of satiation of the rat. If the sarcotesta is complete, and the rat is hungry, then the entire surface of the nut may show striations. However if the rat is not as hungry or there is sarcotesta on only a portion of the nut, there may be a relatively small area of gnawing on the seed. Areas where the nut appears unmarked may be due to small areas of flesh remaining on the shell, which were not removed at the time of gnawing. In the analysed sample these areas covered 1 cm of the surface of the seed. Toothmarks could also be identified on the edges of raised patches of flesh remaining on the nut, but these are unlikely to survive in archaeological deposits. If these are present, they may indicate recent seed deposition. Rodent toothmarks did not occur on the attachment end of the seed because there is no fleshy portion in this location as it joins directly to the sporophyll.

**Breaches to Shells**

Kernels also provide a rich food resource for animals, and several methods are used to enter the woody seed coat to gain access to the kernel. Rodents (Rattus sp., Notomys sp., Xeromys sp., Zyzomys sp. and Mus sp.) use constant static abrasion employing an even distribution of force to create an oblong hole located on the body of the shell or circular holes removing the micropylar or attachment end of the shell (Bang and Dahlstrom 1972; Begg and Dunlop 1980:68; Jones 1994; pers. obs.). The holes placed in the middle of the shell are large enough to partially gnaw the surface of the kernel, with a larger hole required to remove the entire kernel (pers. obs.). Mice create large oval holes in shells (Figure 6-13) in contrast to rats.
*Rattus* sp. uses a variety of methods to open shells to gain access to kernels. Jones reports that *R. fuscipes* prefers to gnaw holes in the end of the nuts (Jones 1994:62). Holes at either the attachment or micropylar end tend to be large and can remove half of the surface area of the shell, resulting in a seed that has only its transverse half present (Figure 6-14).

Differences in rodent gnawing patterns at the ends of shells may inform the analyst if the seed was attached to the sporophyll at the time of predation. A study on rodent patterns of shell predation in *Dioon* sp. and *Zamia loddigesii* populations in Mexico, found that in fresh seeds, the micropylar end was the location where rodents often began to chew open the seeds (Sanchez-Tinoco and Engleman 2004:35). If seeds are attached to the sporophyll, the micropylar end is the only end exposed to rodent gnawing. However if the seed is separated from the sporophyll (which occurs in seeds falling from the cone or at natural breakup on the ground surface), both ends of the shell are available for gnawing. A study of 20 specimens gnawed by rodents in the Sydney Royal Botanical Gardens indicated that there is no preference where rodents attack seeds once they are separated from the sporophyll (Table 6-11).

Rodents can also apply force to produce transverse and longitudinal fractures in Macrozamia shells. The seed is held firmly with the fore feet, gnawing a groove across one of the ends eventually producing a small hole. Rodents may also insert the lower incisors into the hole at the micropylar end pressing the upper incisors on the body of the shell and pressing down at the same time to crack the shell longitudinally (Bang and Dahlstrom 1972:124). While it has also been indicated that rodents leave scratches on the inside of the shells left by the incisors when attempting to pull out pieces of the kernel (Bang and Dahlstrom 1972), these marks were located in only one Sydney Botanical Gardens specimen and may not occur with enough frequency to be used as diagnostic criteria.

**Gnawed Kernels**

Kernels often display features that indicate they have been eaten by animals. These traces include long parallel striations on the surface of the kernel, similar to those emplaced on the outer surface of the nut.
**Spatial Distribution**

The spatial distribution of Macrozamia seeds and fragments in archaeological sites was analysed. All three rockshelter deposits have protected areas where Macrozamia may have been eaten and accumulated by rodents. Seeds and fragments in these areas may also display fracture patterns and toothmarks consistent with exploitation by rodents, and are within the distances recorded for rodent transport of seeds.

**Preservation Biases**

Conditions within archaeological sites are not always suitable for the preservation of macrobotanics and vary considerably within deposits (Clarke 1999:83; Zutter 1999:833). As discussed above, differential preservation of carbonised and uncarbonised remains of Macrozamia remains between excavation units may influence the interpretation of spatial variability, temporal change and quantification (Clarke 1999:83; Hastorf 1999; Johannsen 1988:155; Pearsall 1989:203; Popper 1998; Popper and Hastorf 1988:4). Estimates of biases in the preservation of carbonised remains were made by comparing charred and uncharred Macrozamia remains and by comparisons with charcoal density (weight or percent by weight of fragments in column and bulk density samples and or excavated (layer) samples) and pH (Pearsall 1989:197).

Differential preservation as a result of spatial differences and shelter morphology was also assessed for Cathedral Cave. The biases introduced by differential fragmentation were also assessed. Analysis of vertical and horizontal differences in distribution of specimen size was made. Other cross checks were also used to assess fragmentation using data from faunal and lithic conjoins.

The extent of distortion of fractured specimens due to sedimentary overburden and compression was assessed through the presence/absence of flattened or otherwise distorted Macrozamia remains. Other lines of evidence (faunal remains, lithics) were also used as cross checks on the extent of compression in layers of these sites.

**Fluvial Transport, Deposition of Macrozamia at Cathedral Cave**

As indicated in settling experiments, all the Macrozamia specimens within Cathedral Cave have a high potential for fluvial modification. As such, a number of analyses were
performed to assess the extent of fluvial transport, deposition and reworking of Macrozamia remains. The orientation of *M. moreii* fragments could not be assessed because these data were not recorded during excavation (Beaton unpublished fieldnotes). The three most important lines of evidence used to investigate fluvial transport were 1) analysis of shape, 2) presence of mechanical damage, and 3) presence of fluvial sediment and silt on specimens.

Analysis of the specimen size distribution was used to indicate fluvial deposition, palaeocurrent flow and velocity (Boyd 1990:272; Greig 1989:20; Jones 1987:11). Differences in position and distribution were identified by comparisons of frequency distributions of *M. moreii* remains (size, weight, shape) across the site and indicate possible drops in transport velocities within the shelter area.

Fluvial deposition was also identified by the condition of the organic objects in layers in Cathedral Cave. A range of experiments have been performed in other disciplines which have generated criteria to infer time spent in fluvial systems. Generally, mechanical damage increases as the transport distance increases (Spicer 1991:78). Transport of fresh, weathered or carbonised materials in a fluvial system is indicated by angular tears and breaks in tissues, rounding or abrasion (Spicer 1991:78) and smooth or pitted surfaces of plant parts found in reworked sediment (Hansen 2001:407). Small items are less mechanically degraded and may not be as useful in diagnosis as larger specimens. It must also be noted that not all material enters a fluvial environment fresh, as floodwaters may deposit accumulations of botanical remains in various states of decay (Spicer 1991:78). The presence or absence of damage and the type of damage to macrobotanical remains were recorded in this analysis. The presence of sediment grains, organic particles and silt adhering to specimens was also used to infer the taphonomic history of the specimens.

**Quantification of Macrobotanical Remains**

Most macrobotanical assemblages are difficult to quantify and a range of special methods are required (see Barlow and Metcalfe 1996; Bonzani 1997; Grayson 1984; Hather 1994:60; Miller 1988, 1989; Nelson 1992:240; Pearsall 1989:441; Popper 1988:53-60; Popper and Hastorf 1988:9; Thompson 1994). Macrozamia are relatively easy to quantify compared to other botanical remains because of their distinct morphology.

The micropylar end is a small circular area on the outer end of the seed (Figure 6-15, Figure 6-16) and is characterised by a ring of several triangular teeth, beneath which is a circular
hole with a tissue like tynpanum. In germination, the embryo inside the kernel pushes outward and breaks the tynpanum, and the triangular teeth move outward and the embryo emerges through a set of small teeth which either remain partially intact on the seed or are completely removed leaving a small circular hole (Beck et al. 1988, 1990; Jones 1994; pers. obs.). The micropylar end is still identifiable after fracture. A circular ridge is present with a rounded edge around the inside of the shell around the opening for germination. Identification of the end is reduced when specimens are below 0.5 mm in maximum dimension rather than the effects of taphonomic alteration (for example weathering, acid dissolution or carbonisation).

The attachment end also has a set of external and internal identifying characteristics. The outer surface of the attachment end is often dimpled, and is several millimetres thicker than the rest of the seed (Figure 6-17, Figure 6-18). In M. moreii there is also a slight “table top” effect where the attachment end and its dimples occur on a flat raised area, which aids the seed being held on the stroboli. The attachment end of the seed can also be identified by its internal characteristics. This portion of the shell has an oval zigzag pattern that runs around the inside. Identification of the end is reduced when specimens are below 0.5 mm in maximum dimension rather than the effects of taphonomic alteration (for example weathering, acid dissolution or carbonisation).

In this analysis, a conservative estimate of the minimum number of Individuals (MNI) was based on estimating the completeness of the diagnostic end represented on a specimen. These percentages were tallied for each end of the seed and the largest number was taken as the MNI. Estimates of the percent completeness of each specimen was also tallied and acted as a cross check of MNI. In assemblages collected by multiple taphonomic actors, it is also important to remove specimens added by non-human processes from MNI tallies. However it must be noted that we can never be sure what is missing from the archaeological record (e.g., off site processing) (Pearsall 1989:441).

**Conclusion**

Ecological data can be especially useful in understanding taphonomic actors, processes and effects on Macrozamia remains. In addition, ecological data provide useful data that when used carefully, can be used to understand the wider environmental conditions at the time of collection (Asch and Asch-Siddell 1988:89; Clarke 1988:126; Dennell 1976; Hastorf 1989; Hastorf and Popper 1988; Hather 1994:51; Johannsson 1988; Jones 1987:12; Pearsall 112
1989:195; Popper and Hastorf 1988:12; Zutter 1999:843). The taphonomic processes and estimates of MNI for each site are presented in Chapters 8-10. The arguments Beaton made concerning 1) ceremonial use of the cycad rather than mundane regularity of consumption, and 2) increased seed production through burning are more fully investigated in Chapter 11.
Chapter 7: The Experimental Programme: Investigating the Human Fracture of *Macrozamia Moreii* Seeds

When archaeologists ask questions about...formation processes, they may often have to seek the answers themselves in experimental studies of one sort or another (Schiffer 1974:841).

The methodology of experiment is extremely simple to understand. Its execution, on the other hand, is often likely to be detailed and demanding (Reynolds 1999:157).

The main techniques used by humans, in Australia and overseas, to open *Macrozamia* and cycad seeds are documented in early ethnographic (Gardner and Bennets 1956; Maiden 1889, 1890; Roth 1901; Thozet 1878; Turner 1893), ethnoarchaeological (Beck 1989; Beck et al. 1988) and more recent anthropological accounts (Goodale 1971; Levitt 1981; Meehan and Jones 1977; Thomson 1938). Although most records state that seeds fracture after the application of force, these records do not provide enough data to match the variety of fractured *Macrozamia* remains in the archaeological record with the observed ethnographic record (Lyman 1994:54). Previous research into *Macrozamia* fracture (Beck 1989; Beck et al. 1988, see below) did not provide a sufficient understanding of the cause:effect relationships in fracture or diagnostic criteria through which to identify human fracture of the *Macrozamia* seeds. Thus, variability in the attributes of the archaeological *M. moreii* specimens were not understood.

This chapter presents the results of the human *Macrozamia* processing experiments. These experiments were directed toward 1) gaining familiarity with, and an understanding of, taphonomic effects of human fracture of the seeds, 2) an understanding of specimen variability, and 3) determining diagnostic criteria that could be used to indicate human processing of *M. moreii* remains in archaeological contexts. The value of this experimental work is the development of a set of criteria to understand taphonomic processes and their effects through which to interpret *Macrozamia* remains in archaeological sites.

These experiments had three main goals:

1. To determine if the two ethnographically documented methods of processing the shell (end struck and side struck) resulted in recognisably different fracture patterns.
2. To investigate the impact, if any, of burning, indentor type and the presence of sarcotesta on processing seeds, and subsequent patterns of fracture of *M. moreii* specimens.

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3. To identify diagnostic criteria that could be used to determine the method of processing used in archaeological Macrozamia assemblages, taking into account the effects of trampling and other processes that operate to modify archaeological assemblages.

Macrozamia seeds were amenable to replicative experiments for several reasons. These included: 1) the availability of ethnographic and anthropological descriptions of the methods used to process the seeds, 2) the commercial availability of seeds which could be used for experimental research, and 3) the physical characteristics of the seed itself, which allowed the study of cause:effect relationships and the identification of diagnostic criteria through fracture mechanic analogues.

**Previous Research**

Experiments attempting to replicate the human fracture of *Cycas* sp., *Macrozamia* sp. and *Lepidozamia* sp. seeds have been made by Beck et al. (1988) and Beck (1990). This research was an innovative and important first step to allow archaeologists to understand the processes involved in generating assemblages of fractured cycad remains. However, Beck’s (1990) and Beck et al.’s (1988) research was unable to be used in this analysis. This was because the methods used in the experimental series were inadequately described, the failure to establish clear cause:effect criteria, the limited scope of their conclusions, and questions concerning the validity of interspecies comparisons. A brief discussion of the prior research is presented below.

Beck et al.’s (1988) first experimental test compared the fracture characteristics of aged cycad species fractured in field conditions by traditional owners, and fresh *Macrozamia* sp. fractured under laboratory conditions by the authors. The aim was to identify criteria that could be used to identify the age at which archaeological specimens had been processed.

The aged cycads were described as breaking “in half more evenly and cleanly than fresh seeds retaining sarcotesta”, and that “the surfaces of many fractures tended to be rough” (Beck et al. 1988:143). In addition, there were distinctive “microscopic breakage patterns at the micropylar end of the sclerotesta” (Beck et al. 1988:143). However apart from these general descriptions, no quantitative data was presented, and the methods used to open the seeds were not described. The validity of interpreting taphonomic histories of archaeological
samples of a different species without more extensive investigation or data on cause:effect relationships is questionable.

Beck (1989) conducted an additional set of experiments with *Lepidозамия peroffskyana* seeds. The aim was to identify criteria that could be used to identify the method of opening the seeds. Aged and fresh specimens of *L. perrofskyana* were collected and “cracked with a stone hammer with the anvil in various orientations (end cracking and side cracking)”. The placement of the seed on the anvil and location of the point of force application (PFA) or completeness of the ends at the end of the experiments were not presented. In these tests the microfractures identified in the samples from the first experimental set were not identified (Beck 1989:43).

Beck then investigated whether the completeness of the micropylar end varied between fresh and aged specimens after cracking. Her hypothesis was that for aged specimens, more than 50% of the micropylar end should survive after cracking. Why this end was chosen and why both ends were not investigated was not stated. However the results of this test were significant when the results were pooled but not when taken individually for “end cracked” or “side cracked”, and Beck suggested that this was due to small sample sizes (Beck 1989:44). The results were presented as pooled samples and raw data were unable to be extracted from the table for further analysis (Beck 1989:44).

Beck made some observations concerning the completeness of the micropylar ends after force was applied to their ends. She stated that side cracking resulted in the preservation of “some ends completely intact” while end cracking resulted in “crushed ends”, stating that the micropylar end was “more completely crushed” in end cracking, and that the attachment end was “completely destroyed” when end and side cracked (Beck 1989:45).

The final experiments investigated whether it was possible to determine if archaeological seed fragments had been subjected to further fracture after deposition, as may be produced by trampling. To test this hypothesis, the relative size of the micropylar ends of fresh and aged seeds from the experimental sample (which had not been subjected to trampling) was compared to three archaeological samples. Weight was used as a measure of the size. A Student’s T test of the experimental sample indicated that there was no difference in the size of micropylar ends for either aged or fresh seeds (p = 0.05). Beck found that the size of micropylar ends in two of the three archaeological sites were smaller than those of the experimental set, and suggested that post depositional processes, either trampling or animal damage, were acting to break the micropylar end of the seed (Beck 1989:48). However this a
hypothesis that needs to be tested through subjecting the experimental sample to trampling experiments to properly observe and test cause:effect relationships rather than inferring "ad hoc accommodative hypotheses" (Binford 1981) of the operation of a range of post depositional processes to one end of the Macrozamia seeds.

Experimental Design

Experimental Design Theory


Ethnographic Review

The experimental methodology attempted to closely replicate the conditions and methods used to open both Macrozamia and cycad seeds by hunter-gatherers. As such, an extensive literature review of the methods used to open seeds in ethnographic (Gardner and Bennets 1956; Maiden 1899; Roth 1901; Turner 1893; Thieret 1958; Thozet 1878), ethnoarchaeological (Beck et al. 1988, Beck 1989) and more recent anthropological accounts (Goodale 1971; Levitt 1981; Meehan and Jones 1977; Thomson 1938) in Australia and overseas was conducted. Lithic and faunal experimental literature was reviewed in order to understand general processes of fracture mechanics in brittle objects and also identify key variables which could affect specimen attributes (Binford 1981; Johnston 1989).
Accounts of processing from the Australian and overseas literature were examined for three reasons: 1) increasing sample size may reveal variability in processing techniques which may have been used in the past, 2) broadening the search may reveal more detailed accounts, and 3) to find references dealing specifically with Macrozamia processing. Specific references to Macrozamia processing were sought because they were the main species of interest in this analysis.

It was important to understand this variability because differences in the processing strategies between Macrozamia and cycad seeds were likely to reflect differences in seed morphology, which relate to differences in germination patterns. Cycad species potentially require less PFA and fracture is more likely to be achieved under specific orientations on the anvil and hammerstone. This is because cycad seeds have inbuilt natural seams in the sclerotesta to aid germination, which may affect the path of fracture propagation after force was applied. The ethnographic accounts are briefly reviewed below and further outlined in Appendix Table A-19, Appendix Table A-21 and Appendix Table A-22.

However, there are challenges when using ethnographic and historical accounts. These tend to be short and lack detailed description. The majority of the reports concentrate on the preparation of the edible kernel and not the discarded shell, which in this case, is of archaeological interest. Although they do state that hammerstones and anvils were technological accompaniments, they do not indicate the orientation of the seed to the anvil or where the force was applied by the indenter. There is also general ambiguity due to terminological issues, where “seeds” and “nuts” can mean the outer woody layer or the kernel itself. There are more references to cycad processing than Macrozamia in these accounts. Thus careful reading of the documents was required, sometimes after which the specific processed part was unable to be identified. Anthropological accounts are much more detailed but suffer from a lack of detail in the fracture patterns of seeds. Only three accounts of processing include detailed descriptions of the sclerotesta, and all concern Cycad sp., particularly C. media. Anthropological accounts are also biased towards describing the treatment of the kernel.

Despite these limitations, the reviewed literature indicates that a very general procedure is applied to the processing of both Macrozamia and cycad seeds. Fresh and aged seeds with and without sarcotesta could be processed by the application of force to remove the sclerotesta. These accounts also suggest that seeds could be processed in the fresh state by roasting in a fire (which would have removed the flesh) and then removing the kernel from
the sclerotesta by the application of force. The accompanying technology is also described as being comprised of anvils and hammerstones, where anvils of wood or stone were used to support the Macrozamia seed and indenters were either wooden mallets or hammerstones. Two accounts state that the preferred orientation in Cycas sp. was the attachment end to meet the hammerstone or baton.

These general processing accounts allowed the identification of a cause (percussive force application) and effect (Macrozamia fracture) relationship which were related in time and space and regularly co-incident in accounts of the fracture of Macrozamia seeds (after Binford 1968, 1981; see also Lyman 1994:54). However while these accounts illustrate that fracture is a regular effect of processing, no accounts document the fractured seed in enough detail to interpret the archaeological record from such accounts.

Fracture Mechanics

Organic (and inorganic) materials respond in certain predictable ways when they are stressed. Ethnographic and previous experimental programmes in the fracture of Cycas seeds (Beck 1989; Beck et al.1988) indicate that Macrozamia seeds may respond to applied force in a similar manner to other brittle materials like bone (Johnston 1985:170). Macrozamia shells share many of the properties suitable for the application of a dynamic force that results in fracture. The Macrozamia shell is hard and inert, resistant to deformation, has minimal deformation characteristics, and seems to be without a preferred plane of cleavage. Therefore seeds have the potential for similar morphological responses to dynamic stress and strain as those found in lithic and faunal objects. The seeds are likely to react in consistent ways after the application of dynamic force due to similarity of size, shape and shell thickness that influences the response to strain.

Experimental Variables

It is well understood in fracture mechanic theory that variables can affect specimen attributes. The main variables identified in the ethnographic and anthropological literature were 1) indenter type, 2) point of force application, 3) thermal modification, and 4) point of force application (PFA). Accordingly the experimental design tested the effects of these variables on fragment attributes. A total of 18 experimental sets were defined to investigate the effects of these variables, with each experimental set having a sample size of 20 specimens (Table 7.1).
Experimental Methods

For the “input conditions” of the prehistoric event and the experimental event to be similar, the material and methods utilised must be the same (Young 1989:57). Therefore the same species was used in the experimental tests as identified from the archaeological sites of the CQH. Both wooden and stone indenters were used as indicated by the ethnographic records. Significant variables likely to have affected fracture types and their characteristics were identified from the ethnographic record, including the type of indenter and the roasting of the seeds during processing.

The experiments were conducted in the Archaeological Labspace at the ANU (Figure 7-1). A sample of fresh *M. moreii* seeds were obtained from a commercial supplier. Seeds were still attached to stroboli and they arrived in hesion bags. The weight, length and breadth of all specimens were documented before fracture to ensure comparisons of cause:effect relationships and diagnostic criteria were consistent prior to percussion. Each seed was checked for pre-existing fractures, holes or discolouration, and if found, were removed from the experimental sample. No insulation was used between the hammerstone and the anvil. No one specimen was used for more than one experimental set.

Three different orientations of seeds on the anvil were consistently applied (Figure 7-2, Figure 7-3 and Figure 7-4). Either the attachment end was placed on the anvil and the micropylar end toward the striking direction of the wooden indentor; or the micropylar end was placed on the anvil, the attachment end towards the striking direction of the wooden indentor; or the side was placed on the anvil, and the opposite side met the wooden indentor at the application of force. The location of PFA points were kept as consistent as possible. The angle of force was kept at 90°. Each PFA and resultant fracture paths were documented with “Liquid Paper™” on the seed itself, and the number of PFA’s needed to open the shell at each point was documented by creating a photographic record, in case the seed was destroyed by mould or fungus prior to entry into the database. Throughout the experimental sample a flat slab of volcanic material of granite or schist weighing 2505.1 g acted as an anvil. Two types of indenters were used throughout the experimental programme (depending on set variable tested): Ironbark batton weighing 525.6 g (Figure 7-5), a quartzite hammerstone weighing 813.1 g with a broad, slightly rounded granular contact area (Figure 7-6). Each seed was given a specific identification number and each experimental set was given a number, and each seed was stored in a bag within the greater set bag. A gas mask
was worn at all times to avoid inhaling fumes (see Searight et al. 1995) and chemically resistant gloves were used. At the conclusion of the experiment the Macrozamia specimens were dipped in “Yates Mancozeb Plus Garden Fungicide” and dried at room temperature to inhibit the growth of mould and fungus.

Specimens were heated to examine the effects of burning on fragmentation. Macrozamia seeds (as per conditions above) were heated in the ANU’s School of Archaeology and Anthropology’s electric “Naber” furnace. Controlled by an energy regulator, the furnace has the capacity to reach a peak temperature of 1100 °C, and permits temperatures within 10 °C to be defined (Mercieca 1999:37). The dimensions of the heating chamber were 152 mm by 92 mm by 162 mm (Mercieca 1999:37). The furnace was preheated to the required temperature and 20 Macrozamia seeds were placed inside for a set amount of time. The starting and the finishing temperatures were maintained for the duration of the experiment.

The temperatures the seeds were exposed to were derived from ethnographic accounts of how specimens were placed in the ashes of wood campfires. The realistic range of minimum and maximum temperatures reached in campfires as indicated in experimental analogues in other experiments. The two temperatures which define the upper and lower limits of the temperature scale, approximately 540 °C and 870 °C, are taken directly from hearth fires in other experiments simulating the temperatures of Aboriginal campfires (David 1990; Robins and Stock 1990; Shepard 1968:83). Temperatures of 200 °C, 400 °C and 600 °C were selected for the experiments. Specimens heated to 400 °C represented the approximate heat in ashes and in sediment underneath fires (Gilchrist and Mytum 1986; Stiner et al. 1995) and was used to replicate the temperatures achieved when roasting of Macrozamia seeds. Samples were left in the furnace for 20 minutes as indicated by ethnographic and anthropological records.

Because the force was not applied through artificial mechanical means, inertia variables and force variables (the nature of the force and how it is applied) must be discussed as it has a bearing on fracture types. These experiments could not be performed in a completely controlled manner. The seed could not be adequately immobilised by direct rest and had to be held in place on the anvil using the index finger and thumb of the left hand, because the roundness of the seed and the curvature of the ends increased its susceptibility to move rather than fracture (Hiscock 1988b:19). Other methods of immobilisation including metal tongs or grass twine failed to adequately immobilise the seed. All indenters were held with the right hand while the Macrozamia was steadied on the anvil with light pressure with the
index finger and thumb of the left hand as anthropologically described. As little pressure as possible was applied to avoid the alteration of fracture paths along the shell. Force was applied by hand at 90°, and was applied as consistently as possible. After one hundred seeds were processed the force required became familiar.

Definition of Recorded Attributes

A number of attributes were recorded in order to explain and explore the qualitative and quantitative results of the experimental programme. These attributes are present on both the experimental and archaeological samples and provide an adequate basis in order to make comparisons and inferences concerning within cause:effect relationships between the modern experimental set and the archaeological sample. The recorded characteristics for all experimental sets are presented in Appendix Table A-23.

Qualitative Results and Observations

In the three processing methods, three types of fracture were produced, two of which (longitudinal and transverse) produced mutually exclusive fragment types while a third category of fracture (transverse and longitudinal) occurred in both. These are defined below.

Longitudinally fractured specimens are defined as fractures that have completely split the Macrozamia shell longitudinally into halves or thirds along its longest axis. Longitudinal fragments may contain parts of both identifiable ends. These fractures were routinely produced after force was applied 90° to either end, the specimens were then rotated, and further PFA’s applied to the side of the seed. These fractures are distinctive to this PFA. The indenter type does not alter the main fracture paths produced (Figure 7-7).

Transversely fractured specimens are defined as fractures which have split the Macrozamia along its transverse axis into two complete pieces, along the mid point of the shell. In experimental processing trials, these specimens were routinely produced in side cracking of the seed only. Therefore these specimens can be considered to represent the relationship of PFA to the side of seeds in present and archaeological contexts. These specimens are produced exclusively with this type of PFA. Indenter type does not alter the main fracture paths produced (Figure 7-8).

Transverse and longitudinal pieces are defined as fractures which have split the Macrozamia along its longitudinal and transverse axis. This specimen type was occasionally created when 122
force was applied at an angle of 90°, where fracture propagated aberrantly at 45° away from the PFA. The specimen type usually represents 25% of the completeness of the total seed and 25-33% completeness of either end. These specimens result from transverse and longitudinal fractures of the seed and cannot be considered to be exclusive to one fracture type only. Both types of indenter produce this fracture type in all orientations (micropylar and attachment PFA 1 and side struck) (Figure 7-9, Figure 7-10).

*Body specimens* are defined as a portion of the body of the Macrozamia without any remaining diagnostic end. These variously sized pieces are produced in shatters of the shell during processing or in carbonisation. In processing, these specimens were generated by rebound forces from the anvil. These specimens do not contain a diagnostic end and cannot be used in MNI calculations or to identify the original position of the PFA on the body. The number, size, weight and estimation of the percent area represented by the piece can be collected to obtain estimates of the number of shells (Figure 7-11).

**Diagnostic Criteria Indicating Human Application of Force**

Several other diagnostic criteria were generated in the fracture experiments that indicate the human application of force. In all three processing methods, fracture at PFA 1 was initiated at either a point or a ringcrack. Point initiations left no observable identifying features in the area of the PFA. Ringcrack initiations left a range of identifying features that can be used to infer human PFA. Both point and ringcrack fractures occurred at the PFA 1 and as rebound forces on the anvil. PFA effects at the contact area from the hammerstone and the anvil resulted in ringcracks, crushing, and indicate force and force location. Secondary fracture characteristics included hairline fractures (Figure 7-14, Figure 7-14) related to PFA and anvil rebound forces, shear fractures (see Figure 7-25) and end cracks (Figure 7-12).

**Typical Opening from the Micropylar End**

The initial PFA, positioned at the micropylar end at 90° to the longitudinal axis, created a straight line fracture propagation, with an irregular but characteristic zig-zag fracture edge (Figure 7-18). The specimen was rotated to have its side on the anvil and a second PFA was applied to the midpoint of the shell, which resulted in a straight fracture propagation path extending along 50% of the length of the specimen, which resulted in a fracture with a characteristic straight edged fracture (Figure 7-15 and 7-17). The third PFA was applied and fracture was generated which connected to the initial fracture initiation at PFA 1 to the
fracture generated at the prior PFA, completing the fracture. Fractures were initiated at specific points at the PFA, or in circular areas creating a depressed or ring like fracture (called here ringcrack fractures, see Figure 7-17). Specimens struck at the micropylar end at 90° to the longitudinal axis also exhibited secondary fracture characteristics of body fractures, body hair fractures, cracks through the end of the specimen and ringcracks.

*Typical Opening from the Attachment End*

The fracture characteristics produced by PFA’s to the attachment end were broadly similar to those produced when PFA 1 was applied to the micropylar end and rotated (Figure 7-19, Figure 7-20). The initial PFA created a fracture that propagated in a straight direction, and produced blunt edged fracture (Figure 7-18). The specimen was rotated to have its side on the anvil and a second PFA was applied to the midpoint of the shell which resulted in a straight fracture propagation path, which usually travelled 50% of the way down the longitudinal axis of the seed and produced a fracture with a straight edge. The third PFA was applied and a fracture was generated which connected to the initial fracture initiation at PFA 1, completing the fracture. Specimens struck at the attachment end at 90° to the longitudinal axis also exhibited secondary fracture characteristics of body fractures, body hair fractures, cracks through the end of the specimen and ringcracks (Figure 7-24).

*Typical Opening from the Side of the Shell*

The initial PFA created a fracture that propagated in a straight direction, with a straight fracture edge (Figure 7-21, Figure 7-22, and Figure 7-23). The specimen was rotated and a second PFA resulted in a slightly irregular fracture propagation and a straight edge fracture (Figure 7-23). After a further rotation and the third PFA resulted in a fracture which joined the ends of the previous fractures completing the fracture around the circumference (Figure 7-24). It was this last PFA that resulted in ringcrack characteristics in the midpoint of the specimen. Specimens struck on the side of the seed at 90° also exhibited secondary fracture characteristics of body fractures, body hair fractures, shear fracture (Figure 7-25), cracks through the end of the specimen, shear fractures (Figure 7-25), and ringcracks.

*Quantitative Analysis*

Qualitative analysis confirmed the assumptions underlying the experimental programme and identified specific patterns of breakage and diagnostic criteria of use in analysing
archaeological samples of *M. moreii*. A statistical analysis was performed of the experimental results to more precisely determine the impact of the individual factors affecting the types and extent of fragmentation, and to determine the extent to which the specific method of Macrozamia processing could be identified in archaeological assemblages. Three main statistical tests were generated using SPSS 12 for Windows. Non-parametric tests were selected because few of the results obtained were normally distributed and therefore the assumptions of parametric tests were markedly violated (Cohen 1988; Morgan et al. 2004). The following tests were used:

1. Eta statistic: a non-parametric test that measures the strength of association between a nominal variable and a scale variable.
2. Mann-Whitney test: measures the statistical significance of a result (e.g., probability that the difference in mean is the product of pure chance) where the independent variable has two levels or categories.
3. Kruskal-Wallis test: provides the same measure as the Mann-Whitney test but is used where the independent variable has more than two levels or categories.

**Controlling for Key Variables**

The initial analysis focussed on identifying the relative importance of the type of indentor, presence or absence of sarcotesta, the location of the PFA, and degree of burning on specimens. Not every combination of these variables was able to be tested during the experimental programme; however, sufficient variety was generated to allow systematic analysis of the importance of these factors.

**Identifying Factors Affecting Breakage Patterns**

A number of analyses were generated to identify the nature and strength of the effect of indentor type, burning, the presence of sarcotesta and position of force application on the pattern of breakage. Two data sets were examined. The first data set consisted of the number of blows required to process each seed, and the number of fragments created (attributes of the individual seed). The second data set contained detailed measurements and attributes for each fragment that was created.
**Indentor Effects**

The effects of indentor type on the number of blows required to open seeds was tested by comparing the results for unburnt specimens only to remove the possible bias from the effects of burning. Mann-Whitney tests show that there was no significant difference in the number of blows required to open seeds by indentor \((p = 0.728)\) or the number of fragments created \((p = 0.258)\). Eta was used to investigate the strength of the association between indentor and the number of blows \((\text{Eta} = 0.015)\), and indentor and the number of fragments created \((\text{Eta} = 0.048)\). Both show very weak effects (Cohen 1988). Indentor type had little, if any impact on the number of blows required to open a seed, or the number of fragments created (Table 7-2).

Further analysis investigated if there were significant differences in the attributes of the fragments created. See Table 7-3 for a summary of the results for individual Mann-Whitney tests. The results show that there are no significant differences in the size of fragments created by the two different indentors. Three variables show significant differences: end crack \((p = 0.003)\), body fracture \((p < 0.001)\) and ring crack on the side \((p = 0.013)\). The baton was more likely to create body fractures and end cracks, but less likely to create a ringcrack on the side. Overall, indentor type had a limited effect on the assemblage and no further analysis of indentor effects was required.

**Effect of Sarcotesta**

The analysis of the effects of the presence of sarcotesta was restricted to unburnt specimens because even though sarcotesta was present on burnt specimens, heating the specimens in the kiln burnt off the sarcotesta. Mann-Whitney tests show that the presence or absence of sarcotesta had a significant impact on the number of blows required to open a nut \((p < 0.001)\) and the number of fragments created \((p = 0.007)\) (Table 7-4). The Eta scores indicate that there is a medium strength effect for the number of blows \((\text{Eta} = 0.436)\) but a weak effect for the number of fragments \((\text{Eta} = 0.161)\). During the experimental programme, it was noted that more blows were required to initiate fracture propagation in the shell when the sarcotesta was present than if it was not present. The sarcotesta acted to absorb the force before it reached the inner woody sclerotesta, requiring more forceful blows to achieve fracture initiation and propagation in the sclerotesta. The differences in effort required are illustrated very clearly in Figure 7-26. It is possible that the difference in the force required...
was sufficient to encourage people to use techniques like burning to remove sarcotesta prior to processing, or encourage the collection of weathered seeds.

Differences were also apparent in the attributes of specimens generated between the sample with sarcotesta present and the sample in which the sarcotesta was absent. It is clear from Table 7-5 that body fractures and end cracks are generated more frequently on specimens when there is no sarcotesta present (which acted to absorb the force). Specimen length, overall specimen completeness and the completeness of the ends of the specimens were lower when sarcotesta was present when struck. Mann-Whitney tests demonstrate these differences to be statistically significant ($p = 0.025$ or lower, see Table 7-5 for detailed results). This suggests the presence of sarcotesta has a substantial effect on the effort required to process Macrozamia seeds.

**Effects of Burning**

Several tests were made of the effects of specimen attributes and extent of thermal alteration and indentor type. Specimens were thermally modified at 200 °C and 400 °C. The effects of sarcotesta were unable to be investigated, as although the experimental sample included specimens with sarcotesta present at the time of thermal modification, the flesh was removed by the burning process. Thus, samples opened with the baton indentor were used, and effects of burning analysed on samples without sarcotesta.

Kruskal-Wallis tests reveal that as burning temperature increased, there was a statistically significant decrease in the number of blows required ($p < 0.001$) and increase in the number of fragments created ($p < 0.001$). The Eta scores indicate that there is a medium strength effect of burning temperature on the number of blows ($Eta = 0.425$) and the number of fragments ($Eta = 0.430$) (Table 7-6). There is a notable threshold effect which occurs at 400 °C, where specimen attributes are markedly different in all variables to those unburnt or burnt at 200 °C. The reduction in the number of blows and increased temperature is illustrated in Figure 7-27.

Substantial differences occur in specimen size, completeness and fracture characteristics with increasing temperature. Kruskal-Wallis tests show all differences to be statistically significant ($p < 0.001$ for all variables) (Table 7-7). The threshold effect at 400 °C is apparent with all fracture characteristics except frequency of end cracks and body fragments. Further tests of significance were applied to investigate the differences between unburnt
specimens and those burnt at 200 °C. The differences in weight, the percent of specimens with a fracture through an end, the percent of body fragments and the percent of specimens with partial ringcrack evidence on their side remained significant. Overall, the increased burning of seeds results in greater fragmentation and less effort to open the seed. This is a modest effect if the seed is burnt to 200 °C but a strong effect if burnt to 400 °C. Secondary diagnostic fractures are most likely to appear on seeds burnt to 200 °C.

The Effect of Striking Position

The effects of strike position (side or end) were assessed by analysing burnt specimens and unburnt specimens without sarcotesta, to control for both baton and sarcotesta effects. The basic results are shown in Table 7-8. Mann-Whitney tests indicate no significant difference in the number of blows required to process seeds (p = 0.600) but a significant difference in the number of fragments created (p = 0.020). Eta tests show the latter effect to be weak (Eta = 0.210).

Fragments generated from side striking were larger and more complete than the specimens generated in end striking (Table 7-9). According to the results of Mann-Whitney tests, the differences between side and end striking in fragment size and completeness are statistically significant (p < 0.05 or less) except for frequency of body fragments (p = 0.076), micropylar end completeness (p = 0.671) and attachment end completeness (p = 0.582). The difference in specimen length can be attributed to the PFA location. End struck specimens had fractures that propagated longitudinally along the entire length of the seed (approximately 30.5-40.0 mm), while the side struck specimens effectively dissected the seed in two along the midpoint of the length of the seed, at 15.25 and 20.0 mm. The variations in weight may reflect this difference.

Despite the results of the Mann-Whitney test, the differences in the completeness of either end on end struck versus side struck specimens still appears to be significant (Table 7-9). The presence of ringcrack fractures was higher on the side struck specimens and lower on end cracked specimens. Further examination was made of side and end struck specimens. The results showed important differences between the fragments created by end struck and side struck specimens, matching the qualitative results. Figure 7-28 indicates that side struck specimens produced a comparatively large number of fragments where the micropylar end was 100% complete. However, fewer fragments were created when the specimens where struck on the end, regardless of which end was struck (micropylar or attachment).
Identifying Diagnostic Criteria

Further examination of these factors was made to identify diagnostic attributes that could be used to distinguish between end struck and side struck assemblages, and to understand the impact of burning on identifiability. The analysis focused on the frequency with which two specific identifiable fragment shapes were produced by different styles of processing. In order to remove effects created by sarcotesta and thermal modification, the analysis was restricted to unburnt specimens where the sarcotesta had been removed, and burnt specimens. Only specimens processed using the baton were included. Based on the findings above, the degree of burning was treated as an independent variable. The fragment shapes analysed were 1) longitudinal fragments where some portion of both the micropylar and attachment ends were present, and 2) transverse fragments where either the micropylar or attachment end was 100% complete.

As Table 7-10 indicates, the presence of fragments which had one end 100% complete is a reliable indicator of the use of side striking to process Macrozamia seeds. Similarly, fragments with both ends present are a reliable indicator of the use of end striking to process Macrozamia seed (Table 7-11). Additional diagnostic patterns were identified for the location of specific secondary fractures (Table 7-12). Collectively, this data indicates that the systematic use of side or end striking will leave clear patterns in Macrozamia assemblages. However, it is important to note that these patterns become less marked as burning increases.

Experimental Conclusions

Based on the qualitative and quantitative analysis, four main conclusions were drawn concerning the relative impact of the factors tested by the experiments.

- **Indentor** – Indentor has no significant effect. This could be related to the user adjusting the amount of muscular effort and force required to compensate for variations in the weight and hardness of the indentor in order to break the shell without crushing the kernel within.

- **Sarcotesta** – Sarcotesta was found to have significant effects on specimen attributes, requiring extra energy and more blows to process seeds with sarcotesta present, because the force is absorbed by the sarcotesta. However, sarcotesta is removed from thermally altered specimens as a result of the burning process. The extra effort
required to open the seed when the sarcotesta is present is significant enough to encourage the use of burning to remove the flesh, or the collection of aged seeds where insects or rodents have already removed the flesh.

- **Burning** – Thermal modification has a major effect on the effort required to process the seeds, and on the degree of fragmentation and types of secondary fractures created on the assemblage, which was most marked at 400 °C. Less force was required to open specimens heated to 400 °C, while little difference was noted in force required to process specimens at 200 °C.

- **Strike Position** – The placement of the PFA has a modest effect on size and completeness of the specimens but has a significant impact on the shape of fragments created and the location of secondary fractures. This was further analysed to identify diagnostic criteria that could be used to determine the type of processing used on archaeological Macrozamia assemblages. Results indicate that the estimations of the percent of either end remaining on archaeological specimens can be used to infer strike position.
Chapter 8: Taphonomic Analysis of Cathedral Cave

Archaeological sites are created by people, whose behaviour is more complicated than that of alluvium (Thorson 1996:25)

...sometimes taphonomic problems... will only be partly solved, or not be solved at all (Lyman 1994:352)

Introduction

This chapter presents the results of taphonomic analyses of Cathedral Cave. Questions of site formation and taphonomic processes were examined through sedimentological analysis and taphonomic analysis of faunal, macrobotanical and lithic remains from Cathedral Cave. There were adequate sample sizes for each line of evidence, with a sub sample of 9969 faunal specimens analysed from Units 1, 4, 5, 8, 6 and the roofsqueeze (hereafter RS); a 100% sample of Macrozamia specimens (N=2877) analysed from Units 1, 2, 3, 4, 5, 6, 7, 8, and 9, and a sub sample of 1460 lithic specimens from Units 1, 4, 5, 6, and 8 (Table 8-1). The proportions of each specimen type were distributed differently between units and through excavated levels.

Site Formation

As discussed in Chapter 3, Cathedral Cave has had a complicated depositional history which had not been resolved at the time of Beaton’s excavation or analysis. Before analysis could begin on the archaeological components of the site, three fundamental questions had to be answered that remained from Beaton’s excavation of the site. These were: 1) were the sediments deposited as a result of fluvial events, 2) if so, what effect did fluvial events have on the deposited cultural components at the site, and 3) did the excavation strategy, which excavated “natural levels”, combine fluvial and non fluvial depositional episodes, and if so, was it possible to determine the effects of fluvial processes on the cultural components at the site?

A number of analytic techniques using sedimentological, stratigraphic and chronological data were first applied to understand and construct a model of site formation at Cathedral Cave (see Baker et al. 1983a:235-326, Benito et al. 2002:6, 9; Ely 1997:178; Pettijohn et al. 1987; Springer and Kite 1997:92). An analysis of sediment grain size was used to identify the fluvial formation of the deposit. An analysis of stratigraphic descriptions made, and
photographs taken at the time of excavation by both Beaton (1977) and Tugby (1961) was conducted. Comparison of stratigraphic properties to the characteristics of sediment deposition under slackwater flood conditions were made to understand both cultural and fluvial deposition events, and in particular, the effects of fluvial events on deposited materials. A range of archaeological and geomorphological tests were also applied to investigate the effects of the floods on the structure, location and attributes of cultural specimens in the site. Finally, consideration was given to the effects of the excavation strategy at the site.

The results of these analyses indicate that deposition of sediment occurred as a result of both fluvial and natural chemical and physical weathering of the parent material. The majority of the sediments within Cathedral Cave were emplaced by repeated high stage flood events over the last 4,000 years. These events variously deposited, winnowed and buried archaeological material during high stage flood events.

*Grain Size Analysis*

Several sedimentological analyses of these sediments were performed including 1) range of grain sizes in the deposit, 2) vertical consistency of mean grain size (Mt), 3) vertical consistency of mean grain size (Mv), 4) the derivation of the median, mode and mean grain sizes and consideration of graphic standard deviations (graphic skew, inclusive graphic skew, sorting and skewness), and 5) the mineral content of the deposit.

In total, 21 samples of sediment (each c.100 g) were analysed. Fifteen of the samples were derived from a column sample excavated from the west wall of Unit 3 (Units hereafter shortened to U, e.g., U3), at the eastern end of the shelter, abutting the shelter wall (Beaton 1977). Five further samples were analysed from sediment sampled by Beaton from U4, placed toward the front and near the centre of the shelter. The results from both units characterise the properties of the sediments in these parts of the shelter. Comparisons were made between the sedimentological and stratigraphic characteristics between these two areas of the site in order to understand variations in waterflow across the site. However, as Beaton did not excavate U4 to the same depth as U3, comparisons between the two units are only possible for the upper three levels.

Comparisons of the granulometric properties of the sediments in Cathedral Cave rule out primary deposition of the majority of the sediment as a result of the decomposition of the parent matrix material (Table 8-2, Table 8-3, Table 8-4). The rooffall sample was analysed to
provide the distribution of the range, mode, Mz of clast sizes contributed by shelter breakdown and was compared to the granulometric data from U3 and U4. The results indicate that the rooffall sample has a markedly different mode, mean and median grain size, and different sediment grain sizes in the central two thirds of the distribution (graphic SD) than all the samples from U3 and U4. This indicates that the majority of the sedimentary fill in the Cathedral Cave deposit was not derived from parent rockshelter decomposition. Stratigraphic characteristics were also inconsistent with a model of sediment deposition as a result of rooffall deposition.

The granulometric properties of the sediments in all sampled levels in Cathedral Cave are consistent with the primary deposition of particles from fluvial SWD. Twelve sedimentary samples at the back of the shelter exhibited a mean grain size of 2.5 φ (fine sands), with three strata at the back of the shelter displayed a finer mean grain size of 3.5 φ (very fine sands). Five sediment samples from the front of the shelter displayed both medium and fine-grained sands. The sediments at Cathedral Cave were moderately well sorted, which is also consistent with sediment deposition in slackwater contexts, which range from well sorted to poorly sorted (Kale et al. 2000:342). These grain sizes are the optimal size range for suspended transport in large floods and rapid settling out of suspension in slack water, conditions indicating increasing distance and elevation from the main flood channel (Kale et al. 2000:347).

The variations in grain size between U3 and U4 are consistent with the position of the site in the wider fluvial context and the position of the units in relation to the channel. As discussed in Chapter 3, variations in the range and mean grain sizes within and between slackwater strata are controlled by a number of factors including environmental energy, range of source materials and local hydraulics (position in relation to the main channel, position of deposition in the site and height of deposited sediments) (Partridge and Baker 1987:113). The mean grain size of individual slackwater strata and their stratigraphic position varies directly with palaeoflood magnitude, as higher energy environments deposit coarse to medium sand, while lower energy environments deposit finer sands, silts and clays (Baker et al. 1979; Benito et al. 2002:9). The slight coarsening of the mean grain size to medium sands in U4 indicates proximity to the channel, in comparison to the finer Mz of U3, which indicates distance from the main channel, and a quieter and slower water depositional environment. The mean grain size of fine sands at the back of the shelter in comparison to the medium sands at the front of the shelter is consistent with fineness of particles increasing with increasing distance from the main channel (Baker et al. 1979:7).
The mean grain sizes for all sediment samples in both units at Cathedral Cave are consistent with the mean grain sizes deposited in high stage floods studied in other parts of the world (Figure 8-1). Grain size distributions of Cathedral Cave, fit within the range of grain sizes normally deposited under slackwater deposition (Baker 1987:79; Baker 1994; Baker and Costa 1987; Baker et al. 1979:8; Baker et al. 1983a:230; Baker et al. 1987; Kochel et al. 1982:1165; Partridge and Baker 1987:113). The source of the deposited sediments was the eroded particles of Triassic aged sandstone (Appendix Table A-2) available for transport in the region. Local sources include streambeds, slopes and tributary deposits upstream from Cathedral Cave. These source areas provide the river with a range of grain sizes, which can be delivered and deposited in the main channel and marginal areas (Gordon et al. 1992:292; Partridge and Baker 1987:110). The quantities available determine the amount transported, rather than the ability of the stream to carry it (Gordon et al. 1992:292; Partridge and Baker 1987:110).

**Stratigraphic Analysis**

As discussed in Chapter 3, fluvial geomorphologists have defined stratigraphic characteristics and features common to SWD. Several features are now recognized as useful indicators of sediment deposition in high stage flood events in slackwater environments, and several indicators of areal exposure have been defined. After the excavation was completed, Beaton was able to define and describe 11 major sedimentary strata at the site (Appendix Table A-25), features within them, and their stratigraphic associations. These descriptions were compared to descriptions of features of SWD. The presence of these sedimentary features at Cathedral Cave are consistent with SWD and areal exposure were marked with a “yes” in Table 8-5 and Table 8-6 (see also Chapter 3).

The results of this comparison indicate that there were actually a number of substrata within each of the major strata defined by Beaton. Two main conclusions can be drawn from Table 8-5 and Table 8-6. Of the 11 larger strata defined by Beaton, only four contained cultural remains, including Level 1 across the site (Levels hereafter “L”), L3 (further divided at the time of excavation into L1, L1A and L2 in U6 only); and L3 and L4 in U6 and U7. Records largely concern the fluvial levels, and little characterisation is available concerning the cultural levels of the site, however each of these levels contained some stratigraphic evidence consistent with SWD or areal exposure after fluvial events. Because of the wealth of geomorphological information concerning SWD, analysis of the effects of fluvial
processes on developing occupation deposits and their cultural components focussed on understanding the fluvial events at the site. When viewed as a consecutive series through time, each substrata are coarse grained records of individual SWD and cultural depositional events.

Reinterpretation of the stratigraphy of the site is possible using SWD data. It is clear from Beaton’s descriptions, and comparison to literature about SWD formation, that L3 (including U6L1, IA and 2) and in L1 across the site are high stage flood events that have variously winnowed and buried archaeological material built up in periods between flood events (Ely 1997:178). Photographic data also indicates that the cover of cultural levels by silt occurred. It is also clear from photographic evidence that in certain levels of the site, sediments were deposited and eroded as a result of these fluvial events, as indicated by photographs taken during excavation. Silt and clay sediments are usually deposited either in the initial or waning stages of high stage flood events (Baker et al. 1979:4, Ely 1997:182; Kochel et al. 1982; Springer and Kite 1997:94). The occurrence of silt in and on top of cultural layers was identified by Beaton for L3 across the site (Figure 8-2, Figure 8-3). Synaeresis cracks, or “clay cracks”, were identified in U2L4, which indicate both the fluvial deposition of fine sediments and a period of areal exposure allowing cracking (Figure 8-4). A major erosive event occurred in the front of the site in the upper 30 cm, at approximately 1,040 BP, and more recently a “clump” of combined plant and faunal material (Figure 8-5) was deposited in L1, indicating that floodwaters carrying debris loads covered the site. In addition, features consistent with the expulsion of gas bubbles through fine-grained sediment are also present (Figure 8-6).

**Chronology**

It is clear that people occupied the site between flood events, but the clarity of the timing of their visitation is low due to the actions of the floods and the excavation strategy. Beaton obtained several age determinations for the site, which were used in this analysis. In addition, a further 12 determinations were obtained in this analysis from strata from different excavation units of the site to construct a more detailed chronology (Figure 8-7, Appendix Table A-3 and Appendix Table A-4). Absence of organic material in some fluvial layers prevented the carbon dating of those layers. Following the considerations of Baker et al. (Baker et al. 1983a:235; Baker et al. 1985:344) and Kochel et al. (1982:1173), samples submitted for age determinations were carefully selected. Organic samples from different types of organic materials including wood, Macrozamia and seeds from *Eucalypt* sp., were
submitted from different layers and units at the site. No inversions were obtained for the site (Table 8-7).

The determinations in this sequence indicate a fairly continuous depositional model for Cathedral Cave. However the dated sequence largely reflects periods of fluvial sedimentation. This is largely a consequence of the lack of collection of in situ material for future radiocarbon analysis, and a result of the excavation of “natural” levels, which conflated both cultural and fluvial records. The literature concerning SWD indicates that seeds and wood are commonly entrained on the upper water surface of the floodwaters (wood, leaves, twigs, seeds and nuts), which float until waterlogged when they become deposited (Baker et al. 1983a:235). Thus, dates obtained from Eucalypt sp. seeds and wood were probably deposited in the upper stages of the flood. However, organics including Macrozamia also are winnowed, transported and deposited in slackwater events (Chapter 6), and although these seeds had diagnostic attributes suggesting they were humanly struck, two forms of data (discussed below) suggest that at least a small portion of the Macrozamia collection was transported from areas upstream of the catchment and deposited in Cathedral Cave.

The age determinations and general depositional sequence were compared to regional and Australian records of palaeoflood events, in order to attempt to identify the possible timing of the human occupation events at the site, and cross check the original reinterpretation of the stratigraphy. It was likely that the floods in Cathedral Cave would reflect larger geomorphic processes, as floods are not random events through time; and are related to changes in climatic regimes (Greenbaum et al. 2000:951), occurring in response to relatively small changes in average climate conditions (Nott 2003:52). Regional syntheses of palaeoflood chronologies in rivers around the world indicate that the largest floods during the mid Holocene cluster into distinct time periods that are related to regional and global climatic fluctuations (Chatters and Hoover 1992; Chorley et al. 1985; Ely 1997:175).

If the stratigraphic sequence at Cathedral Cave truly reflects large-scale palaeoflood events, then this should be reflected in known dates of flood events in the region (Table 8-7). The data from Cathedral Cave closely reflect the available palaeoflood deposition records from other parts of the region and the continent more generally. The record indicates that high stage fluvial events occurred frequently in the mid-late Holocene, reflecting mid-late Holocene climatic variability.
Bell et al. (1989) suggest that in the CQH, the earlier part of the Holocene had a less variable climate. Three dated flood events were identified from 3.5 m of sediment from the Nogoa River, to the west of Carnarvon Gorge (Bell et al. 1989:455, Finlayson and Brizga 1995:184). A “severe” flood event was identified at 3550 ± 70 (3.5 m depth below ground surface). Bell et al. (1989) also suggest that during the latter part of the Holocene, large scale flood events were more frequent, occurring at roughly 500 year intervals. They identified two recent flood events in the Nogoa River: a severe flood event at 1080 ± 60 (1.20 m below ground surface) and a flood event which occurred approximately 500 years ago (0.5 m depth) (Bell et al. 1989:455).

These floods are also present in the Cathedral Cave deposits. Fluvial sediments in U2L8 returned an age determination of 3560 ± 80 BP (ANU 1762), closely matching the timing of flooding in the Nogoa River. Organic material from fluvial L2 returned an age determination of 1040 ± 80 BP, with the flood at 500 BP possibly indicated by the erosive disconformity and clump of organic debris in U1L1. As can be seen in Table 8-7, the age determinations of several other flood events dated at Cathedral Cave correspond to other palaeoflood dates other areas in the north of the continent. A return interval of approximately 564 years is indicated by the palaeoflood record at Cathedral Cave, closely matching Bell et al.’s estimation of 500 years (1989).

It is beyond doubt that Cathedral Cave was regularly flooded, and inundation of the site was common from prior to 3,600 BP to the present day. Studies of SWD indicate some water movement over SWD’s and the potential for winnowing of faunal remains and carbonised plant remains, and the deposition of a range of organic material (refer Chapter 6). Beaton’s excavation strategy conflated non-fluvially deposited material with fluvially winnowed records, creating a mixture of autochthonous and allochthonous assemblages.

**Taphonomic Implications of Floods at Cathedral Cave**

The above discussion raises important questions concerning the interpretative meaning of the organic materials at the site which need to be addressed. Three main questions were: 1) can the presence of flood events be detected on specimens, 2) can the effects of floodwaters (e.g., winnowing) be detected on cultural components, and 3) and what are the implications of the operation of fluvial events and excavation strategy on the interpretation of the cultural materials in the site? These questions were addressed through the analysis of 1) estimates of
settling velocity indicated by mean grain size data, 2) the mean weight of specimens per level and unit, 3) the representation of Vooohries groups, 4) spatial patterning in specimen shape, 5) analysis of weathering stages, 6) analysis of manganese dioxide uptake, and 7) analysis of the spatial distribution of specimens with any fluvial evidence, including silt coverage and abrasion. Orientation of specimens was unable to be used in this analysis as the data was not collected at the time of excavation. The above analyses were performed on a total sample of 9969 faunal specimens (Table 8-8) from Units 4, 5, 8, RS, 1 and 6 and a total sample of 2877 specimens of Macrozamia from all units of the site (Table 8-9). This approach also allowed the analysis of spatial variance in fluvial activity.

Velocity and Sheer Stress

The grain size data at Cathedral Cave indicate that waterflow across the site has not been an entirely passive process. The sediments and the archaeological “clasts” within them were not deposited in completely still, quiet water conditions. The grain sizes of medium and fine sands indicates that there was some movement of water and particles across the Cathedral Cave deposit to suspend fine and medium sands in the wash load (B. Finlayson pers. com. 2000, see also Kochel et al. 1982:1173). The grain size data indicates that current velocities were strongest, faster and more turbulent, towards the front of the site closest to the main channel, where fine and medium sands were deposited (Units 4-8). Based on the common logarithms of settling velocities and grain diameters at 20 °C, the medium sands in the front of the shelter indicate much higher settling velocities of 3.98 cm/s\(^{-1}\) where clasts rapidly fall out of suspension (Pettijohn et al. 1987:73). In addition, the proximity of the front of the shelter to the mouth of Boowinda Creek Gorge tributary also suggested that velocity and turbulent eddy flows were higher in this area.

In comparison, flow velocities were lower in the back of the site, which is relatively marginal to the main channel, preferentially deposited finer sands (Partridge and Baker 1987:113). The common logarithms of settling velocities and grain diameters at 20 °C indicate that fine sands at the cave were probably deposited at a low turbulence, slow settling velocity of 2 cm/s\(^{-1}\), while the very fine sands were deposited at a settling velocity of 0.794 cm/s\(^{-1}\). At these rates particles gradually fall out of suspension and are deposited. This data indicates that winnowing of the materials in the site may have occurred, and that there may be significant differences in the distribution of material from the front to the back of the shelter.
Voohries Groups

The potential for differential representation of elements from different Voohries Groups was analysed. The differential representation of elements from Petrogales and Macropods were compared to those identified experimentally for isolated dog and sheep elements (Voohries 1969; see also Martin 1999:77, Table 2.8) as these were the closest available analogue to the Australian context.

Results indicate that for Cathedral Cave overall, both Petrogales and Macropods have similar mean Voohries group results, both falling in Voohries Group 2, indicating some fluvial winnowing may have occurred. Petrogales had a mean Voohries of 1.92, and Macropods a mean Voohries of 1.80 (Table 8-8 and Table 8-10). However this result is somewhat tempered by the observation that elements in Voohries Group 1, and those intermediate between groups 1 and 2, are those commonly deleted by canid gnawing (including ribs, vertebrae, sacrum, sternum, scapula, phalanges and ulnas). Elements from Macropods and Petrogales that are in Voohries Groups 2 and 3 (e.g., femur, tibia, humerus, pelvis and mandible) commonly remain after gnawing, largely as a result of high structural density. Therefore the evidence of winnowing based on this test is ambiguous, and further investigations were conducted.

Spatial Distribution

The potential for fluvial sorting of bones was investigated due to the generally low flow velocities indicated at the site and the wide surface of the deposit on which sorting could occur (Table 8-11). In all levels the mean weight of specimens was less than 1.0g. A pattern in the spatial distribution of specimens was identified, with mean weights consistently lower at the front of the shelter (0.368-0.468 g), in comparison to those at the back of the shelter (U1: 0.486 and 0.647 g; U6: 0.958 and 0.455 g). Again, the completeness of specimens was smaller in the front of the shelter (U4:17.28; U5: 15.32; U8:16.81) in comparison to the back of the shelter (U1:28.25%; U6 18.61). This data is consistent with the sedimentological and grain size data, and suggests that velocities at the back of the shelter were lower, creating lag deposits of larger sized bones in the back of the shelter.

Shape

The shapes of specimens were also investigated as shape has a strong influence on whether specimens are moved and transported (Lyman 1994:177). “Axial ratios” of length, width and
thickness (Frostick and Reid 1983; see also Martin 1999) were calculated in order to place all specimens into one of four general shape categories used in sedimentary analyses of transport and deposition of specimens. The shapes of the specimens in all levels of the site were dominated by blade shaped specimens (55.8%), followed by rods, (25.9%), disks (12.8%) and spheres (5.5%) (Table 8-12, Figure 8-8). Each level and unit at the site displayed the same patterns of dominance by these two shapes, which are considered to be “indicator shapes” as they lag behind after fluvial processes (Martin 2000).

Sedimentological tests indicate that these shapes have a competent settling velocity of less than 12 cm/s (see Martin 1999:39), which is consistent with SWD which form in flows of less than 1 m/s (Benito et al. 2002); and are comparable with the settling velocities identified at Cathedral Cave. In addition, the Macrozamia settling experiments (refer Chapter 7), indicated that all fragment shapes of Macrozamia would be transported by fluvial processes.

*Weathering Stages*

As is discussed further below, the weathering stages of faunal specimens at Cathedral Cave were low, the majority with a weathering stage of 0, with only 17% in weathering stage 1 or more (Figure 8-9). This was a very low rate of weathering in comparison to the other sites. Behrensmeyer has indicated that a weathering profile constructed from fluvially accumulated bones has ambiguous significance for inferring duration of accumulation, as specimens that have been weathered are less buoyant than non weathered bones, and are less susceptible to transport by fluvial events (Behrensmeyer 1978, Chapter 4). The weathering stage data in Cathedral Cave may also then indicate at least a partially fluvially modified assemblage.

*Manganese Dioxide*

Several hundred specimens displayed incorporation of manganese dioxide, formed by manganese oxidizing bacteria, which prefer moist, anaerobic environments (Shahack-Gross et al. 1997:440). The highest counts occur in levels that were subjected to fluvial events, U6L3, U6L4 and U1L3 (Table 8-8). While these specimens may indicate association with floods, it is not possible to interpret whether the modification is related to repeated fluvial events at this time.
Abrasion

As discussed in Chapter 4 and 6, water transport and movement is often found to cause abrasion on both faunal specimens and organic matter. A total of 1.2% (N = 115) of faunal specimens contained evidence of abrasion, with 4% or less of specimens in each layer of the site exhibiting abrasion (with the exception of U8L1, U6L2) (Table 8-8). Evidence of abrasion on Macrozamia specimens in Cathedral Cave was also investigated. As discussed in Chapter 7, Macrozamia seeds were found to have a grain size equivalence to silt, and would be transported and deposited in flood events at the site. A total of 1.2% of the Macrozamia assemblage displayed fluvial abrasion; and where sample sizes permit analysis, the highest evidence of abrasion on Macrozamia specimens was contained in U4L3 at 13.4%. Such high levels of abrasion are consistent with higher velocities and turbulence in units at the front of the shelter.

Sediment Cover

Lithic and faunal specimens were examined for adhering sediment of particular grain sizes consistent with those suspended in slackwater. Sediment was found on the surface of lithic artefacts, and in the medullary cavities, trabeculae or outer cortical surfaces of bone. The presence of sediment on these specimens indicates final stage movement and the “lag” of these parts of the assemblage at the time floodwaters receded from Cathedral Cave. At Cathedral Cave 4% of the specimens displayed silt coverage, which were distributed in low quantities in levels of the site which also contained evidence of a palaeoflood event, including U1L1 (3%), U6LA (1%), the RS (14%). Lower numbers were identified in the second major stratigraphic level of the site (between 1200 BP and 2300 BP), from the front of the shelter in U5L3 (1%) and U8L3 (1%) and at the back of the shelter in U6L1 (2%), and U6L1A (1%). That the majority of the evidence is contained in the RS (N = 324) and U1 (N = 50) is consistent with sediment and stratigraphic characteristics for this part of the site which indicates quieter, low flow conditions, where fine sediment sizes could settle out. Analysis also indicates that specimens with silt covering were larger than those specimens that did not have silt covering (Table 8-13), and supports the interpretation that the specimens displaying this feature may have been part of a lag deposit at the site. The highest counts of Macrozamia specimens which were covered by silt sediment occurred in U7L1, U7L1A and U1L3; all units at the back of the shelter where lower velocities and less turbulence allowed silt to settle on these specimens.
Stratigraphic Integrity

The fluvial history of the site, as well as variations in sediment density, induration and consistency (Table 8-2, Table 8-3, Table 8-4), suggest that vertical and horizontal mixing might have occurred in the deposit. As has been discussed previously, fracture, compression and distortion of components as a result of sediment burial processes are likely in the lower levels of the deposit and in those levels adjoining fluvial levels, however this was unable to be tested (refer Chapter 4). Issues of stratigraphic integrity and the extent of vertical movement was assessed through refitting of faunal specimens, rather than scatter plots of weight, or analysis of the size distributions of the specimens; as these two latter tests produce ambiguous results in fluvial contexts due to sorting and winnowing.

Refitting data suggest that inter-level movement has been minimal, and may be related to turbulent boundary flow in flood events, which has mixed small numbers of specimens between layers. A total of 344 faunal specimens were conjoined during this analysis at Cathedral Cave, the majority of which were refitted from the same level (Table 8-14). The percent of specimens in each level that could be conjoined ranged from 9% (U6L2) to 2% (U1L2, U4L3, U5L1, U6L1) (Table 8-15, Table 8-10). The units at the front of the site (U4, U5 and U8) had lower rates of conjoining (2-5%) than those at the back of the site (0.4-9% in U1 and U6). When analysed by level, the upper two levels of the site had the highest rates of conjoining in comparison to the lowermost levels of the site. Conjoins in L3 ranged between 2-9%, and between 2-6% in L1.

At Cathedral Cave, a total of eight conjoin sets were refitted between levels. Five were identified during this analysis, and three were identified when Archer and van Dyck identified cranial specimens in the 1970s (Table 8-16). The generally low levels of conjoins between levels is not surprising given that deposition of large sedimentary strata occur between most levels containing faunal specimens, and the possible winnowing of some specimens from the deposit. The conjoin data also indicate that fluvial events have been able to entrain some specimens and deposit them in separate levels. These specimens vary in the maximum vertical and horizontal distance separating the pieces within the conjoin set. Specimens in one conjoin set, a tooth and a mandible, were vertically separated by a horizontal distance of 12 m between units and a vertical distance of 1 m (U1L3 and U6L3). These results were similar to Behrensmeyer’s concerning teeth and elements in fluvial contexts (Behrensmeyer 1975). All other inter-level conjoins occurred in the upper four levels of the southeastern end of the deposit, in U1 and U2.
Overall, this evidence also suggests that had the sedimentological and stratigraphic data not been available, these analytic tests would have suggested that fluvial winnowing had occurred at Cathedral Cave. The results of these analytic tests indicate that caution in the interpretation of the organic components at the site is required. Several conclusions were drawn: 1) winnowing probably occurred at the site, 2) differences in the distributions of material related to flood velocity and winnowing between the front and back of the shelter, 3) the potential of different biases in different classes of remains e.g., the meaning and the significance of the plant remains may be difficult to interpret due to both fluvial and cultural deposition and conflation in excavation; fauna were winnowed but may largely be “intact” while stone may also be largely intact. However, although careful consideration must be given to the interpretations of the meaning of the archaeological components, there remains significant potential for the re-interpretation of the remains, the human history at the site, and to reconsider the evidential support for the previous models of site use.

**Differential Preservation**

At Cathedral Cave, there was no evidence of root etching (see Lyman 1994:375-6; Haglund and Sorg 2002). Although modification from a range of animals and insects were considered in the analysis (Chapters 4 to 7), no positive identifications were made. There was some evidence of weathering on lithic artefacts ($N=9$), which probably indicates a limited amount of raw material recycling occurred at the site. Large blocks of rooffall were identified in the lowest excavated strata (180 cm depth, c.3560 BP) across the western half of the site in both Tugby’s and Beaton’s excavations (Beaton 1977, 1991b, Appendix Table A-25). However, these rooffall blocks were situated in culturally sterile fluvial sediments, below the levels containing the lowest cultural material.

Several other taphonomic processes affected specimen preservation during the formation of the deposit at Cathedral Cave. Major taphonomic processes affecting faunal preservation were identified as 1) weathering, and 2) canid deletion and modification of elements. Detailed analyses of the effects of pH and the differential preservation of burnt and unburnt specimens were unable to be considered, as pH data was not collected for the site. Also, pH values are likely to have varied considerably over time from variations in moisture caused by repeated flooding of the site.

Previously, little was known concerning the formation of the roofsqueeze and its depositional relationship to other parts of the site, or the depositional context of these
specimens. Conjoin data from this portion of the site (Table 8-14) (based on 110 specimens (5%) and 58 specimens (7%) which refit between the RS and U1L3 respectively), indicates deposition of elements began sometime after a previous fluvial event c.2300 ± 70 BP. The specimens in RS were considered separately for almost all taphonomic variables and qualitative and quantitative statistics. This is because the area is a separate "site" formation area within the larger site, as it was a natural trap, and although areally exposed, was largely protected from sequential taphonomic processes which affected other remains in the site (e.g., burning).

**Weathering**

As indicated above, specimens displayed minimal evidence for weathering, which may be partly related to fluvial deposition and winnowing, and fast deposition of a protective layer of sediments from fluvial events. A total of 6011 specimens (60.29%) formed the analysed sub-sample of faunal remains comparable with Behrensmeyer's (1978) experimental set (refer Chapter 4) (Table 8-17). The analysis of the weathering stages of specimens in some units and levels was not possible due to low sample sizes (U1L4, U2L3, U3L3, U4L2, U5L1, U5L2, and U6LA). The percentage of specimens within each level considered for the analysis ranged between 28-87%.

The results of the weathering stage analysis indicate that the mean maximum weathering stages (MMWS) of the RS was much higher at 0.98 (close to weathering stage 1) in comparison to the MMWS of all other units and levels of the site, which was 0.24 (less than 1/4th that of the RS) (Figure 8-11, Figure 8-12, see also Figure 8-13, Figure 8-14, Figure 8-15). Analysis of the distribution of specimens in each weathering stage in the RS and other units and levels indicates that the RS contains higher counts of specimens of all weathering stages, particularly those between MMWS 1-3; in contrast to other units and levels.

Spatial and vertical variations in the weathering of specimens were analysed. Results indicate that weathering increases with depth in all units and levels (Figure 8-16, Figure 8-17, Figure 8-18). The MMWS for the upper three levels of the site are highest in U4, U5 and U8 located in the front of the shelter, in comparison to those in the back of the shelter (U1 and U6). For example, the MMWS in L1 in the units in the center of the site ranged between MMWS of 0.27 (U4L1) to 0.76 (U8L1) in comparison to the back of the shelter which ranged from 0.10 (U1L1) to 0.08 U6LA. The same pattern also occurred for increased MMWS of specimens in L3 at the front of the shelter was evident, where MMWS ranged
between 0.45 (U5L3) to 0.77 (U8L3); in comparison to the units at the back of the site which ranged between 0.14 (in U1L3), 0.16 in U6L1 (equivalent to U1L3). Unfortunately, the lowest levels of the site containing faunal remains occur in isolation in U6, and here the results show variable results with depth. The MMWS for U6L3 was 0.32, higher than the MMWS for the level beneath, U6L4, where the MMWS was 0.16.

Following Behrensmeyer (1978, see also Lyman 1994), the relationship between weathering stages and animal body sizes and depth was investigated to analyse if the weathering distribution was caused by differential effects of frequency and distribution of animal body sizes in the deposit. The differences in the MMWS do not appear to be related to animal body size (as indicated by animal weight). When the distribution of animal body sizes between levels of the site was analysed, results indicate that all body sizes (unknown, small, medium and large) are present in all levels of the site, and are distributed generally consistently throughout the levels (Table 8-18, Figure 8-19). Two trends were identified in the MMWS data for body weight. In all levels, animals of larger body sizes and weights (Macropods) were more extensively weathered than unknown, small and medium sizes, with specimens of unknown body sizes having the lowest MMWS of all. There also seems to be some variation in the relative rates of weathering stages achieved by each animal body size between units and in levels of the site (Table 8-19). Overall however, the very low mean max weathering stages (MMWS 1) suggest that weathering has not been a major factor in differential specimen preservation at the site.

**Canids**

Canids have been important agents of accumulation, modification and deposition of faunal items in Cathedral Cave (Table 8-20). A conservative estimate of canid modifications identified that approximately 32.7% \((N = 3260)\) of the faunal sample displayed evidence of gnawing, digestive modification or both. Canid taphonomic effects were almost equally divided between digestion \((N = 1567, 15.7\%)\) and gnawing \((N = 1384, 13.9\%)\), with significantly fewer specimens displaying evidence of both modifications on the same specimen \((N = 309, 3.1\%)\). However 67.3% \((N = 6709)\) of the assemblage lacked unambiguous attributes consistent with canid modification. Similar patterns in canid modification were identified whether analysed by weight or counts (Figure 8-21, Figure 8-22, Figure 8-23).
The evidence for canid modifications were unevenly spatially distributed between all units of the site (Table 8-21 and Figure 8-20). Canid effects were twice as high in the RS in comparison to other units and levels of the site. Evidence or both canid gnawing and digestion were highest in U8L3, U6LA and L1A, and L4, U5L1 and 2, U4L1 and L2; and 3, U1L4 and the RS. Digestion was high in U1L1 and U1L2, U8L1, with gnawing dominating modification types in U5L3, U1L3, U4L3, U6L1, U6L2, and U6L3.

The Faunal Component at Cathedral Cave

A total of 9969 faunal specimens weighing 6960.08 g formed the analysed sample from Cathedral Cave. The fauna was distributed unevenly across levels and units (Figure 8-21, Figure 8-22, Figure 8-23). A total of 49 species were identified from Cathedral Cave, of which 43.36% (N= 4323) could be identified to species level, and 73.3% were identified to element (N= 7322).

In general, the species represented at Cathedral Cave are similar to both Rainbow and Wanderer’s Caves due to shared environmental similarities. There are proportionally more Petrogales at Cathedral Cave, possibly due to the adaptation of rock wallabies to sandstone gorge systems (Strahn 1995). However the representation of large Macropods is lower, due to the lack of nearby grassy plains preferred by Macropods (Menkhorst and Knight 2001; Strahn 1995). Cathedral Cave has more snakes and lizards, less bandicoots and gliders, and similar counts of possums in contrast to the other two sites. The fauna was dominated by Petrogale sp., Trichosurus sp. and Macropod sp., when analysed by MNI (Table 8-23) and NISP (Table 8-22). Over half of the specimens were from animals of medium body sizes (56.6%, N = 5657), with comparatively fewer specimens of elements from smaller body sizes (12.4%, N = 1243) and larger body sizes (5.8%, N = 577). Where age could be determined the sample was dominated by adults (21.10%, N = 2109).

Human Actors on the Faunal Assemblage

Although humans are clearly indicated in site occupation events, the question of who was responsible for the faunal remains is a significant issue that requires several types of analyses to disentangle. The actors on the faunal assemblage were further investigated. The most direct line of evidence for human interaction in the faunas included 1) evidence for butchery, and 2) evidence for the thermal modification of species and elements. The latter data are important to determine the timing of burning events.
**Faunal Butchery**

The most direct evidence for human association and modification on prey carcasses is the identification of taphonomic traces of butchery (Lyman 1994). However, there was very sparse evidence for human modification of faunal elements in Cathedral Cave. A total of 29 specimens (0.29%) displayed traces of butchery evidence, comprised of: cutmarks ($N = 13, 0.1\%$), hackle marks ($N = 10, 0.1\%$), ribs ($N = 8, 0.08\%$), and point loading ($N = 7, 0.07\%$) with low frequencies of chattering and bone flakes ($N = 2, 0.02\%$) and single examples of slice marks, incipient ringcracks, impact crushing, and overlapping percussion indentations ($N = 1, 0.01\%$). Evidence for butchery was low in all levels of the site, ranging from 0-2% in most levels. The highest count occurs in the RS (0.3\%), followed by U1L1 at four traces (0.20\%), with remaining butchery evidence sparsely distributed through all levels and units of the site, between zero and two taphonomic traces.

The low frequency of positive evidence for butchery at Cathedral Cave was comparable to both Rainbow and Wanderer’s Caves, and also consistent with Solomon’s (1985) experimental results (Chapter 4). The low rates are also consistent with studies in other parts of the world where relatively low frequency of butchery evidence is identified in archaeofaunas (see Bar-Oz and Dayan 1999, 2000, 2002, 2003, 2004). However, even though sample sizes are very low, the overall pattern of traces identified as resulting from butchery modification are suggestive of purposive human butchery behaviours (see Lyman 1994). The evidence also supports the inference of human involvement with the faunal assemblage, particularly the large Macropod component.

Loading point and cutmark data are both associated with large limb elements of Macropods and Petrogales (A-26). Loading points were mostly associated with large Macropod marrow bearing elements, the tibia and femur, which have been ethnographically documented as being split for marrow (see Solomon 1985, Solomon and David 1990, see also Chapter 4). Loading points are also associated with other supporting lines of evidence of the human application of force including hackle marks and crushing, and were not associated with trace fossils made by canids. The data is consistent with ethnographic, anthropological and experimental evidence as being the best location to apply point of force to extract marrow, and was repeatedly located on femurs, which have the highest marrow content, and occurs on the same element on the same species, suggesting anatomical purposiveness (location to extract marrow).
Faunal Thermal Modification

On the whole, the thermal modification record at Cathedral Cave is consistent with archaeological and forensic experimental analogues. A comparison between the archaeological and the experimental data suggests that the majority of faunal specimens were unintentionally thermally modified either on top of the sediments or within the sediments at reoccupation events, rather than by intentional “cooking” activities. The evidence for this position is outlined below.

Distribution of Burn Extent

At Cathedral Cave, 20.12% (N = 2006) of the faunal specimens displayed evidence of thermal alteration (Table 8-25). In comparison to both Rainbow and Wanderer’s Caves (Figure 8-24, Figure 8-25), Cathedral Cave has a significantly lower rate of burning, which would be consistent with incidental burning within a large site with deep stratigraphic units. Figure 8-26 (see also Figure 8-27 and Figure 8-28) shows the proportion of classes of thermal modification extents through levels and units for Cathedral Cave. When the proportion of specimens in each thermal modification extent is analysed by level and unit, there is a consistent pattern of dominance of calcined specimens in the surface levels (specimens in L2 are excluded as they are solely fluvially derived), and generally lower proportions of all other burn extents. The third level of the site in all units and levels show much less calcination, and lower proportions of specimens in other thermal modification extents. This pattern is generally consistent with the results of several experiments into correlates of in situ thermal modification (refer Chapter 4).

The distribution of calcined specimens was further considered following the data provided in Stiner et al.’s (1995) experimental sample (refer Chapter 4). The calcined to carbonised ratio overall for the site was 1.6, however significant differences in the ratio were identified when units and levels at the site were compared (Table 8-25). In all levels except the surface level of the site (with the exception of fluvial levels) carbonisation, rather than calcination, is dominant. Level 1 in the units at the back of the shelter display high levels of calcination (10.76 in U1L1, 1.45 in U6L1) in comparison to the units at the front of the site (U4L1 and U8L1, 0.68 and 0.54 respectively). The similarity in the archaeological and experimental datasets suggests the thermal modification of fresh animal bones at the site, and that fires were consistently placed near the middle of the shelter floor area, and were relatively
constant in duration, extent and temperature, but may have been relatively infrequent.

Further analysis was conducted to investigate why the surface level of the site had such high rates of calcination.

In other sites, such a pattern was further investigated using sediment rates and differential loss of carbonised to calcined specimens. Unfortunately the relationship between sediment rate and thermal modification of this pattern was unable to be analysed at Cathedral Cave as it was likely to have been biased by fluvial deposition of sediments. The differential loss of incompletely carbonised specimens in comparison to calcined specimens is unlikely, as experiments have indicated that faunal specimens with organic content resist fragmentation as a result of thermal modification of the organic portion (Stiner et al. 1995:223).

It is unclear whether the high recent level of calcination in the faunal specimens in the surface layer of the site is entirely due to Aboriginal activities or due to the high visitation, camping and lighting of fires by Europeans. According to Walsh (1999), Cathedral Cave was extensively visited and was treated as a camping ground by European visitors from the 1930s to 1980s. Therefore the variations in the extent of calcination in the upper levels of the site may reflect a combination of Aboriginal and European fire 1) frequency, 2) intensity, 3) duration, 4) content of bone on the surface of the site, or 5) or disposal of bones into the fire in site clean up activities (Gilchrist and Mytum 1986).

Evidence for the roasting of animals as indicated by ethnographic evidence and in experimental cooking trials were also investigated (refer Chapter 4). This data suggest some representation of the activities of cooking variations may be identified by investigating 1) animal size, 2) animal age, 3) variations among the eight most commonly occurring species, and 4) variations among the 13 most commonly occurring elements. Sample sizes were too small to consider burning modification by element and species.

Any original patterns appear to have been substantially altered by further thermal modification at later fire events (Tables 8-26, Table 8-27, Table 8-28, Table 8-29). Rates of burning are generally consistent across animal age, body size, species and elements, providing no evidence of selective burning relating to cooking activities. When analysed by the ratios of calcined to carbonised for these categories, high calcined ratios for unidentified long bones was high, perhaps reflecting reduction of specimens as a result of calcination. While calcined to carbonised ratios vary by age, species and element, the variation does not
match the expected patterns if this was caused by cooking. The most reliable use of this score is to identify intensity and duration of fires for layers across the site.

The overall rate of burning by animal size was 23.1% burning on large animals ($N = 133$), 18.3% on medium ($N = 1037$), 12.8 on small ($N = 159$) and 26.9 on unknown ($N = 677$) body sizes. All classes were more calcined than carbonised, ranging from 2.86 for specimens which could not be identified to animal body size based on size reduction due to thermal processes to 1.11 for large and 1.31 for small animals. Overall, this data suggests that all specimens in all body sizes and age groups had an even chance of being modified while on the surface of the deposit. The ratio of calcined to carbonised specimens of the most common species and elements in the site were also analysed. Only snakes ($Boidae$), possums ($T. vulpecula$) and Macropods ($W. bicolour$) displayed less extensive thermal modification than the other species in the site. Interesting variations also occur on elements, although it seems to be an essentially random pattern of modification as large sized and smaller sized elements are modified to different stages.

The extent of thermal modification on faunal specimens becomes clear when evidence for burning was analysed 1) over fractures (Table 8-31), and 2) interiors (Table 8-32 and Table 8-33). These results also support the inference that the majority of the thermal modification occurred after edible meat was removed, and after the specimen was discarded. The majority of thermally modified specimens have burnt fracture surfaces, and burnt interiors, with 89.2% displaying burning over the fracture surface and the interior of the bone. This feature also does not vary by layer and was consistent over the site. This pattern was very similar to Rainbow and Wanderer's Caves. Research suggests that this form of fragmentation occurs as a result of in situ modification as a result of proximity to fires, or deliberate discard of bone into the hearthfire rather than in cooking (Stiner et al. 1995).

Overall, there is very little direct evidence for human butchery and intentional thermal processing of the vertebrate remains at Cathedral Cave. Direct evidence of percussive force to marrow rich long bones of Petrogales and Macropods was consistent with ethnographic data for the processing of these species. The interpretation of the thermal modification data suggested extensive taphonomic overprinting of original human signatures as a result of open fires, especially in the surface level of the site. The vertical distribution of thermally modified specimens, the consistent proportions of calcined to carbonised specimens in most layers of the site, the consistent proportions of calcined to carbonised specimens in each layer by animal age, species, element, colour and surficial changes to thermally modified
faunal specimens indicates that the majority of faunal specimens were unintentionally burnt both within and on top of sediments.

The pattern at Cathedral Cave is consistent with a number of experiments conducted in both archaeological and forensic sciences (Chapter 4). The results can be read to indicate that the majority of the burning of the bone occurred when the bone was fresh (prior to weathering Stage 2). However, this may not indicate the repeated occupation of the site by humans, as a fresh supply of bones may have been provided as a result of an increase in dingo activities in the site (discussed below). The recent increase in calcined specimens may reflect a difference in fire history at the site, or alternatively may reflect increased camping and thermal modification by visitors to the gorge in the recent period, which at times, had up to 20,000 people over the period of a few weeks (Walsh 1999).

**Canid Actors on the Faunal Assemblage**

As indicated in Chapter 4, even though clear modification effects were evident on faunal specimens, there are considerable challenges in identifying the primacy of humans and dogs in the deposition and modification of prey species represented in faunal assemblages. Recognising this, several analytic tests were applied to the faunal assemblage at the site. The patterns of dog modification are very similar for count, sum of completeness and sum of weight (Figure 8-29, Figure 8-30, Figure 8-31).

The frequency of canid modifications by animal body size for all species was analysed to assess the potential contribution of small and medium body sizes to the Cathedral Cave deposit by dogs. The results for all of the three CQH sites indicate that the archaeological pattern is similar to modern ecological patterns (Table 8-34). It is notable that the rates of dog modification, particularly digestion, increase as animal size decreases. The rate of digestion is 30.6% ($N = 379$) for small animals, 16.3% ($N = 9.7$) for medium animals and 7.3% ($N = 42$) for larger animals. The particular animals digested also overlaps with modern ecological studies (Table 8-35). These results indicate that small and medium animals were an important part of the diet of the dingo in the CQH region, and are consistent with modern ecological studies (Corbett 2001).

Given this result, subsequent investigations focussed various attributes of Petrogales and Macropod specimens to investigate primacy of human and canid involvement with these main prey species at Cathedral Cave (refer Chapter 4). Several analyses were performed,
including 1) digestive and gnawing evidence on Petrogales and Macropods, 2) the age structure of the Petrogales and Macropods in Cathedral Cave, 3) differential representation of body regions, 4) differential representation of elements, and 5) diagnostic regions on elements.

The evidence of digestive and gnawing modification on Petrogales and Macropods at Cathedral Cave suggests significant canid modifications (Table 8-36). Petrogales show higher rates of all canid modification types, with 43.7% \((N = 1354)\) in comparison to Macropods at 37.1% \((N = 60)\). When analysed by canid modification type, most of the digestive evidence was contained on Petrogales 17% \((N = 523)\) in comparison to Macropods 12% \((N = 47)\). Most of the gnawing evidence was also identified on Petrogales 31.8% \((N = 977)\), rather than Macropods 25% \((N = 97)\). Very similar proportional frequencies of modification types and species selection were also identified at Rainbow and Wanderer’s Cave. The focus on Petrogales is consistent with modern ecological data (Corbett 1994).

The evidence of digestion and gnawing modification by age groups on Petrogales and Macropods at Cathedral Cave had the potential to more directly inform concerning the agent of predation (Table 8-37). However, there were no obvious patterns other than a lower rate of dog modification on Macropod young (Table 8-38, Table 8-39). Of the specimens where animal age could be determined, 13% of dog modified Petrogale specimens were young, while 25% of dog modified Macropod specimens were young. This pattern may reflect the canid modification of human caught Macropod prey, or could reflect individual or pack hunting of Macropods in the gorge.

Variations also occur by unit and level of the site for juvenile specimens, with digestion increased relative to the overall site average. The rate of gnawing on juveniles was much higher than the mean for the site in the RS, U8L1 and U8L3. Gnawing evidence was higher than the site average in Petrogale and Macropod adults also in the RS, and also in U5, and most levels of U6. Both gnawing and digestive modification evidence suggests gnawing reduction of juveniles occurred on site between 2,300 BP (L3) in several areas across the site: in U5L3, the RS, U1L3.

The differential preservation of body regions was analysed for Petrogales and Macropods at Cathedral Cave (Table 8-40). The data from Cathedral Cave suggest decreased representation of forearms, back, chest and feet relative to the hindlimbs (Hudson 1993), for both Petrogales and Macropods. The differential representation of hindlimbs in comparison to all other body regions is consistent with patterns identified in canid modified...
archaeofaunas by Hudson (1993), and also with studies on Australian dingoes by Solomon (1985) and David (1984). Overall, the results are consistent with, and therefore suggestive of, extensive canid modification (Solomon 1985, David 1984). These patterns are inconsistent with the natural disarticulation sequences for Macropods ascertained by Reed (2001), and Read and Wilson (2004).

Patterns of digestion and gnawing on the skeletal elements of Petrogales were also considered (Table 8-41). Unfortunately, sample sizes for Macropods were too limited to interpret trends. The patterns of Petrogale elements represented in scats displaying evidence of gnawing modification are consistent with available ecological data concerning the preferences of the dingo (Solomon 1985, David 1984). At Cathedral Cave, Petrogale elements most frequently displaying evidence of digestive modification included the 4th metatarsal 22.5% (N= 29), caudal vertebrae 38.2% (N= 42), cranium 7.4% (N= 19), mandible 10.4% (N= 15), femur 17.0% (N= 97), humerus 24.4% (N= 21), phalange (foot) 40.0% (N= 20), tibia 15.8% (N= 80), and pelvis 10.8% (N= 35).

Further tests were conducted to investigate the extent of canid in situ deletion of elements of Petrogales or Macropods at Cathedral Cave (Table 8-42, Figure 8-32, Table 8-43). Results of the analysis of epiphysis to shaft ratios of Petrogale and Macropod femurs and tibias are consistent with canid modification of long bone elements. Petrogale femurs and tibias have a low representation of epiphyses (0.24% and 0.14% respectively), and a similar result was obtained for Macropod femurs and tibias (0.20% and 0.05% respectively).

Within Element Gnawing Selectivity (landmarks)

Two further testable models of gnawing selection on element landmarks were investigated to differentiate human only, from canid only or both actors’ involvement with Macropod assemblages in Cathedral Cave. A hominid butchered bone assemblage offers a carnivore a “shortened menu of parts and a reduced nutrient yield compared to what is available on a complete animal carcass” (Blumenschine and Marean 1993:275). In the CQH this may have consisted of grease from defleshed limb epiphyses and axial bones, possibly some flesh attached to bones around the vertebral and cranial processes, and exposed long bone shafts with remnant marrow in cavity and access to epiphyseal ends of long bones. Blumenschine and Marean (1993:275) suggest that 1) hominid butchery restricts the parts that offer nutrients to canids, but will offer some nutrient rich packages (epiphyses), 2) carnivore selection of parts for consumption from a hominid butchered assemblage should differ from
its preferred choices from whole carcass, and that the choices would also differ from selection chosen from whole carcass killed by the canid.

Large samples displaying repeated patterns of modification to particular elements, regions of elements provide compelling evidence for carcass processing activities of dogs. The gnawing frequency on each element of Petrogales and Macropods was calculated by using presence/absence of landmark data for elements and species (see Chapter 4). A relative landmark survival factor (RLMSF) was derived, where landmark survivability of each landmark of each element was scaled by the highest MNE for the element and species. The landmark data was used in several ways: 1) to investigate overall survivorship patterns and assess the degree of fit with available experimental and ecological data for whole carcass reduction by dingoes only, 2) to identify patterns of gnawing over ends of associated elements or joints, to identify if the carcass was articulated at the time of reduction, and 3) to investigate if loss of specific landmarks on specific elements was related to the presence of meat on the carcass at the time of gnawing (Figure 8-33).

Overall the pattern of reduction of Petrogale elements at Cathedral Cave is consistent with whole carcass modification by dogs as identified by Solomon (1985), Solomon and David (1990), and the lair data from David (1984). Also consistent are the reduced relative survivability of the thorax region as a whole, and the lack of survival of the distal pelvis, phalanges, and distal ulna and radius, scapula, articulations of the centrum on vertebrae, spinous processes of vertebrae and the epiphyses and near epiphyseal regions of the tibia and femur. Viewed the other way, survivability of the shafts of the long bones, proximal mandible and centrum of the vertebrae are consistent with element survivability of canid reduced skeletons in experimental (Solomon 1985) and ecological data (David 1984).

Patterns of gnawing as inferred from RLMS of elements indicate that the carcass was articulated at the time of canid reduction. The strongest evidence for this was contained in the pattern of gnawing of the phalanges of the hands and feet, and associated articulated elements of the feet and forelimbs (Figure 8-33). The pattern for both regions suggests gnawing up the arms from the hands to the middle of the forelimbs, and in from the toes to the middle of the foot, in both cases ceasing as bone structural density increases. The pattern of survivorship around the proximal ulna and the proximal radius, and the distal humerus, is also consistent with gnawing around this articulated joint. Also consistent is the same pattern displayed in the femoral-pelvic joint, where the lateral protuberances of the proximal femur
have been removed but the head of the femur and the acetabulum show higher survivorship rates.

Not only do Petrogale carcasses appear to be articulated at the time of consumption, patterns of gnawing and survivorship are correlated with the presence of meat on bones. This is inconsistent with a model of human primacy and secondary dog access to carcass remnants, where removal of landmarks on high meat bearing elements should not be associated with meat in any way. The fact that this is not occurring in the archaeological record for Petrogales supports argument for in situ reduction of meat in Petrogale carcasses by dogs. This suggests that meat was consistently associated with these elements at the time of gnawing for there to be consistently repeated patterns of modification to these elements. This pattern is clearest in three regions of the carcass: the head, the abdomen and the hindquarters.

Patterns of modification of the skull and pelvis are consistent with a model of association of high tissue areas. Consistent loss and gnawing evidence at the “distal” mandible (near the massenteric muscle) is possibly related to reduction of the skull for the brain tissue or the massenteric muscle. This pattern is consistent with several other studies of canid modification of skulls (Binford 1981; Hudson 1993) and suggests that the dogs had access to the complete skull with meat still attached. The pattern of modification to the cranium also suggests that the rich nasal tissues and brain tissue was also consistently available. The pattern of gnawing to the pelvis is also indicative of whole carcass reduction. The loss of the thin distal pelvic region is often gnawed and digested as a consequence of reduction of the abdominal cavity. The loss of ribs in the thorax is also consistent with meat and tissue availability.

The most compelling evidence for whole carcass reduction of Petrogales is observed in analysis of the differential RLMSF of the posterior proximal tibia and the dorsal posterior femur (Figure 8-33). In the distal posterior femur and posterior proximal tibia are closely related to the position of the calf muscle and its fibers. The relationship between the location of gnawing evidence and large muscle groups was analysed by considering the relative survivorship of those landmarks of the femur and tibia in close association with this muscle. Results indicate that a pattern exists for lowest survivorship of those landmarks directly associated with the calf muscle, on both the tibia and the femur.

Five patterns are evident in the tibia landmark survivorship values:
1. The relative survivorship is lower along the posterior portion of the tibia, which is closely associated with the calf muscle and tendon.

2. The posterior surface of the proximal tibia is associated with the highest density of calf muscle tissue, and has the lowest relative survivorship of all the landmarks of the tibia (0.01 to 0.5 out of a total of 1).

3. The relative survivorship for landmarks across the proximal and distal posterior face associated with the calf muscle are consistently lower in comparison to the anterior face of the tibia which is not associated with high values of muscle tissue and which show higher relative survival frequencies.

4. The pattern is also present in the posterior surface of the distal femur, which is associated with the calf muscle and has a survivorship of 0.5. Preferential gnawing and the lower relative survival of the posterior surface of the distal femur is suggested in comparison to immediately adjacent surfaces of the bone. The relative survivorship of the opposite surface on the anterior surface of the femur (0.86), or the posterior surface of the midshaft (0.82) is much higher than that associated with the tibia calf muscle.

5. Further reduction of the epiphyses of the distal femur and proximal tibia also occurred for reduction of within bone nutrients (spongy bone). The survivorships for the epiphyses were also very low (0.02 for the proximal epiphysis of the tibia and 0.16 to 0.24 for the distal femur epiphysis).

The overall age distribution for the site is consistent with a canid predator selective attrition model for Macropods and Petrogales. This is consistent with ecological data, which suggests single hunting of non-adult Petrogales by dingoes. An age distribution of Petrogales and Macropods consistent with canid selection was also identified at Rainbow Cave for Petrogale sp. Canids hunting in packs, or humans alone, could have predated the adult Macropod samples. Results obtained for Cathedral Cave are similar to those from other Australian taphonomic analyses of canid modifications to archaeofaunal assemblages which suggest that due to canid modifications very little animal bone in archaeological sites can be directly attributed to human agency (Solomon 1985; Walshe 1999:63). The condition and range of species in the assemblages strongly suggest dingo only deposition or at least significant secondary modifications at the sites.
Rodent Actors on the Faunal Assemblage

At Cathedral Cave a total of 333 (3.3%) faunal elements were gnawed by rodents (Table 8-44), and compared to the both Rainbow and Wanderer’s Cave, rodents have been more of a taphonomic actor on both the faunal and the Macrozamia assemblage. Of the total sample of rodent gnawed bones, most were concentrated in the RS (N = 293; 2.93% overall; 12.9% for level). Comparatively high levels of gnawing were also located in the area around the RS, including U1L1 (0.08% overall; 0.4% within level, N = 8) and U1L3 (N = 19; 0.19% overall, 2.3% for level). The remainder of the specimens which had been gnawed by rodents (N = 13, 0.13% overall site) were spread through the deposit, with one specimen from U4L1; U4L3, U5L2, U6L2; two specimens from U8L1 and U5L3 and five specimens from U6L4. Skeletal elements of rodents were also identified from the RS, U1L4, and U6L3 supporting the idea that rodents were living in the site (Lyman 1994). The selections of bones gnawed by rodents appear to be non-random in all units and levels where long bones appear to be preferentially selected. The gnawing data for the RS and U1L3 suggest that the RS may have been used as a shelter for rodents from 2,300 BP until it was effectively sealed from their use by further sedimentation.

The rodent gnawed sample from the RS was selected for further examination because of good sample sizes and clustered rodent gnawing. The mean dimensions (weight, length and width) of faunal specimens displaying evidence of rodent gnawing were analysed to investigate if rodents were preferentially selecting for particular features of bones. There does appear to be some patterning in the selection of bones by rodents in the RS. Gnawed bones (N = 293) are more than twice as heavy and almost twice as long (2.36 g and 45.91 mm respectively) in comparison to the ungnawed sample (N = 1982, 1.07 g and 26.75 mm respectively), with gnawed bone also slightly wider than ungnawed bones (10.01 mm and 12.76 mm respectively). Preferred elements gnawed in the RS appear to be femur (N = 65), pelvis (N = 55), tibias (N = 34), 5th metatarsal (N = 22), ulna (N = 21), and rib (N = 23), these possibly related to sample size, with all other elements less than ten specimens were gnawed. The weathering stages of all of the faunal sample in the RS ranged from stage 0-5, with rodent gnawed bones covering the same range of weathering stages, with rodent gnawed bones showing only slightly higher rates of weathering than ungnawed bone (0.81 and 0.79 respectively, both close to weathering stage of 1). There was no significant difference in weathering stages between the two samples, with the mean weathering stage of the gnawed and ungnawed bone sample both at weathering stage 0.
The Macrozamia Assemblage

A 100% sample of Macrozamia specimens from all units and levels at Cathedral Cave formed the analysed sample of 2,877 specimens (Table 8-45), the highest NISP of all the three sites. All specimens were considered in order to reconsider the quantitative support for Beaton’s prior arguments concerning Macrozamia density at the site. Macrozamia specimens were distributed unevenly between all units and levels (Figure 8-34). The highest count was in U1L1 of 682 specimens, followed by U2L3, which contained 433 specimens; U4L1, which contained 316 specimens; and U1L3, which contained 234 specimens. All other units and levels had between 1-170 specimens.

A range of seed fragment types were represented at the site (Figure 8-35). These included sclerotesta with part of a diagnostic end attached (60.79% $N=1749$), specimens without a portion of an end (non-diagnostic body specimens, 30.99%, $N=1093$), sporophyll pieces (0.45%; $N=13$), sarcotesta (0.34%, $N=10$), kernels (0.31%, $N=9$) and complete seeds with kernels inside (0.10%, $N=3$). These types were distributed unevenly between units and levels of the site. However roughly even counts of specimens with part of an end of the seed were present in U1L3, U4L2, U5L1, U6L1A, U8L3, and U9L1 with large divergences in all other levels and units.

Non-Human Agents of Macrozamia Modification

It was possible to clearly identify the taphonomic agent opening the Macrozamia shell in 32.56% of the specimens ($N=937$) (Table 8-46). Although several animals were identified as possible taphonomic agents of seed collection, transport and predators, only rodents and insects were identified as taphonomic agents at Cathedral Cave. However they were a minor feature of the assemblage affecting a total of 1.25% of the seeds.

A total of 196 specimens (6.8%) of the Macrozamia assemblage at Cathedral Cave had evidence of rodent gnawing on the outer shell, emplaced as a result of eating of the outer fleshy sarcotesta. This was the lowest rate of gnawing at the three sites (e.g., 23.9% at Rainbow Cave and 13.5% at Wanderer’s Cave). The gnawing evidence was clustered in and around the units nearest to the plant in the site, specifically in U7, ranging between 9.5% (U7L1) and almost 28.6% (U7L2); and U6 in LA where almost 17.6% were gnawed (Table 8-47, Figure 8-36). Relatively few seeds ($N=3$, 0.1%) had evidence of rodents opening the shell to eat the kernel. Insects, specifically Macrozamia grubs ($A. zamiae$), were a much greater taphonomic agent at Cathedral Cave in comparison to rodents. Thirty-three
specimens (1.14%) displayed insect modification and were distributed in the upper levels of the site: in U1L1 (N= 13, 0.45%), U1LA (N= 12, 0.41%), U7LA (N =4, 0.13%) and one specimen each from U7L1A and U6L1 (0.03% for the site). Cathedral Cave had the highest count of insect attrition and the lowest rates of rodent opening of the three sites.

**Human Agents of Macrozamia Modification**

Several features of the Macrozamia assemblage suggest that the majority of seeds may have been opened as a result of human force. All fracture patterns analysed for Cathedral Cave were consistent with those generated in the experimental set. Direct evidence of human processing of the specimens included 1) fracture patterns produced as a result of the human application of force, and 2) thermal alteration of specimens consistent with anthropogenic temperatures obtained from experimentally processed Macrozamia.

**Fracture Techniques**

Analysis of the completeness of ends and ringcrack data suggests that humans used side striking to open the seeds in the site. Over the site as a whole, 12.2% of the specimens have a complete end, in comparison to 5.3% which have parts of both ends (Table 8-48, Table 8-52). The results of the experimental tests indicate that high frequencies of specimens with complete ends are produced in side striking techniques (refer Chapter 7). At Cathedral Cave, the same patterns hold in all thermal modification extents, suggesting a consistent reduction pattern over the site as a whole. Higher frequencies of transversely fractured specimens containing complete ends occur in all thermal modification temperatures (13% at 0 °C; 10% at 200 °C, and 19% at 400 °C). In comparison to longitudinally fractured specimens containing portions of both ends (5% at 0 °C, 5% at 200 °C and 8% at 400 °C).

A second line of evidence was used to analyse opening techniques. The placement of ringcracks of the side of the specimen also suggests side striking. At Cathedral Cave, 26.6% of the specimens not thermally modified contained evidence of PFA ringcracks positioned on the side of the nut. Higher rates of ringcracks on the side of specimens rather than the ends occurred in all temperature groups (Table 8-49, Table 8-50 and Table 8-51) specimens heated to approximately 200 °C displayed 20.1% ringcracks on the side of the specimen and 0.2% at the end; and at 400 °C no specimens displayed evidence of ringcracks on the side, in comparison to 22.0% which displayed ringcracks on the side. The same pattern was evident
for unburnt specimens which had no evidence of ringcracks at the end, but had 26.6% ringcracks on the side.

While the overall evidence suggests that side striking was the preferred method to open the shell, there is also some evidence that both side and end cracking were used in some levels of the site (Table 8-52, Table 8-53). In certain units of the site, transversely struck specimens with a complete end are dominant (U1, U2, U3, U4, U5), however marked change in U6 and U7, and U8, where both types exist: sometimes dominated by end striking, or side striking or nearly even proportions. At this point it is suggested that these differences may relate to personal choice of the people undertaking seed processing rather than increase in force generating increased diversity of fracture types. This is because the degree of force used seems to be relatively consistent as indicated by the similarity in the percent end completeness of both ends in U6 and U7, and U8.

A significant proportion (76.5%) of specimens did not display direct evidence of human PFA (Table 8-52). However, this is consistent with taphonomic modification identified from the experimental trial (Chapter 7), which indicated a reduction in the evidence of PFA occurs on specimens that have been thermally modified (Table 7-7).

Specimen fragment type (portion shape) was used to further investigate human processing of specimens not showing evidence of PFA, as consistent fracture shapes were generated in the experimental trials (Table 8-48, Table 8-54). Shape types at Cathedral Cave were dominated by specimens which had been transversely and longitudinally fractured (“both”) at 44.0% \((N = 1265)\); body portions (“neither”) (39.3%, \(N = 1132\)) which were created at PFA or anvil rebound fractures; transversely fractured specimens (11.7%, \(N = 336\)) and 5.0% longitudinally fractured specimens \((N = 144)\). Shape data shows some differences between the sites. All sites have generally low rates of longitudinal specimens, ranging between 1.8 and 5.0%, of the sites, however Cathedral Cave has the highest counts of longitudinal specimens; and in all other shape categories are closer to those in Rainbow Cave than they are to Wanderer’s Cave. As is explained further in the Macrozamia section in the Wanderer’s Cave Chapter, the differences exhibited at Wanderer’s Cave are largely due to the extensive size reduction as a result of carbonisation of specimens in the lower portion of the site.
Heating of Macrozamia from Processing

The Macrozamia specimens at Cathedral Cave were almost evenly divided into specimens which did not display evidence of thermal modification \((N = 1396, 48.52\%\), and thermal modification to low temperatures \((N = 1295, 45.0\%\), while fewer specimens showed carbonisation \((N = 186, 6.46\%)\) (Figure 8-37). Fluvial winnowing processes may have acted to winnow carbonised specimens at the site as Cathedral Cave has the lowest rates of unburnt specimens of all the three sites, and also has slightly less specimens in all burn stages (Table 8-51 and Table 8-49). Settling tests on several complete and fractured Macrozamia specimens (Chapter 7) indicated that both complete seeds and carbonised Macrozamia fragments floated, and would be removed from the site. All other uncarbonised fragment shapes sank, with settling velocity data indicating that they would be subject to movement in turbulent flows. As discussed above, Macrozamia specimens displayed evidence that they had spent part of their post depositional history within a fluvial system. Therefore, a conservative interpretation of the Macrozamia specimens at the site suggests that the record of Macrozamia processing at the site has not been completely preserved, but may only indirectly reflect human activities at the site.

Age of Seed at Processing Time

The age of the seed at collection and processing can be identified using taphonomic indicators of weathering and the presence of sarcotesta (Chapter 6). Sample sizes are too low to consider relative age of the seed for U6LA, U7L1 and U4L1. Overall, 49% of the Macrozamia assemblage displayed signs that it had been weathered; however this was unevenly spatially distributed between units (Table 8-55, Figure 8-38, Figure 8-39). Overall, upper levels of the site have more weathered specimens than the lower levels of the site; ranging from 20% in U6L3 and 9% with the exception of 49% in U1L3. Rates of weathering are highest in U1.

Very few specimens contained evidence of sarcotesta at the site (3.5%), and Cathedral Cave had the lowest count of specimens with any evidence of sarcotesta (Table 8-48). At Cathedral Cave the sarcotesta evidence was unevenly distributed across levels and units, with most of the evidence contained in U2L1 where rodents secreted shells, and in units nearest the Macrozamia plant in U6 and U7 with lower numbers in U8, U9 and Units 4S away from the parent plant (Figure 8-40).
Overall, a number of conclusions can be drawn concerning Macrozamia use at Cathedral Cave by considering 1) seed density, 2) MNI of seeds, and 3) using ecological data to infer the use of the plants and their seeds. The density of Macrozamia remains in Cathedral Cave is lower than described by Beaton who estimated the density at 400 specimens per m³ (Beaton 1977, 1991). A total of 2,877 specimens, from an estimated volume of excavated sediment of 27.2 m³, equates to an average density of 105.8 specimens per m³ (discussed further in Chapter 11). However, almost all of the specimens were located in the top 50 cm of the site (N = 2870). Because of this, more accurate reflections of specimen densities were derived by estimates of excavated sediment volume of 8.1 per m³ for the upper 50 cm across the site. This returns an estimated density of 354.3 specimens for the top 50 cm of the site. This density estimate is most similar to the lower end of Beaton’s original density estimate for the site of 400-600 specimens per m³.

Even though the density of specimens at Cathedral Cave is similar to that proposed by Beaton (1977, 1991b), the actual estimates of the minimum numbers of complete seeds in the site was very low. The factors which may have affected the calculations of MNI were assessed. Thermal modification does not appear to have affected completeness of specimens as similar completeness estimates were returned for each thermal modification extent: 18.9% at 0 °C, 15.6% at 200 °C, and 19.7% at 400 °C (Table 8-56, Table 8-58), and as such is not considered to have caused a major bias on MNI (Table 8-50, Table 8-59).

Two methods were used to estimate MNI for the site as a whole: estimates of overall specimen completeness, and summing the estimations of end completeness (Table 8-57). MNI estimates indicate low numbers of specimens for the site. An estimate of MNI based on the sum of specimen completeness for all specimens indicates a MNI of 503.05 nuts. However the MNI estimates drop when the sum of the estimations of the completeness of diagnostic ends are used, where 445.28 nuts are indicated based on micropylar end completeness, and 408.58 nuts are indicated when based on attachment end completeness. The MNI estimates indicate slightly more than one stroboli for the last 4,000 years at the site, and even when a conservative estimate of one nut to account for all the NISPs at the site, 2,877 nuts equates to 9.6 stroboli (where one stroboli contains 300 nuts).

Interpretations concerning seed and cone availability at the time of human use of the site, and Macrozamia in the area around the site were analysed through 1) evidence for collection of cones, 2) weathering data, and 3) rodent gnawing patterns. Chapter 11 fully discusses the ecological data on which the following interpretations are made.

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The presence of a Macrozamia plant in the site has made taphonomic issues concerning agent of deposition especially important at Cathedral Cave. The presence of both sporophyll parts and structures from the inner core of the stroboli were indicative of transport of complete stroboli to Wanderer’s Cave (refer Chapter 10). However the presence of sporophyll structures in Cathedral Cave merely indicates break up of the cone from the plant in the site and dissemination of pieces across the floor of the deposit by humans, rodents and floods. At Cathedral Cave it is not clear whether humans transported the seeds into the site, or collected available seeds off the ground surface. Several lines of evidence suggest the collection of seeds from cones that have started to disseminate, possibly collected in non-masting phases of seed production in parent plants. Only six levels of the site have data which support collection of seeds in a masting year, all the evidence is clustered in U6 and U7, which are both located nearest to the Macrozamia plant in the site.

Humans appear to have discarded seeds with rodent breaches and insect breaches or both. The insect data suggests that insects were active near the plant in relatively recent times U6La and U7LA, insect data indicates fresh cones with fresh sarcotesta to consume. Low activity may indicate a coning event due to low breaches and satiation of the insect. Also low association of both human and insect evidence on seeds indicates people are not taking entire cones from plants as they were at Wanderer’s Cave, and may suggest seed collection off the floor of the shelter. The data is in contrast to Wanderer’s Cave, which suggested human collection of fresh cones from trees with insects.

Weathering data also suggests the collection of seeds weathered beneath the trees, rather than rodent collection of fresh seeds which have then weathered in the site, as the weathering stage is consistent with specimens weathered in natural environments under trees. Weathering data are related to three principle factors: collection of fresh specimens off the tree or from around the base of a plant after a recent coning event and collection of aged seeds from the base of the plant (<12 months). This interpretation is also supported by fracture data, which indicates that Macrozamia in the upper levels not burnt but weathered, in contrast to lower levels which have burning and fresh seeds (Table 8-60).

Overall, the presence of both fresh and aged seeds in the site through time is a pattern which is consistent with modern ecological data for seed availability in Macrozamia populations, and suggests people are using fresh cones collected off plants, and seeds from prior coning events. Overall, the pattern suggests that people are using seeds naturally available in the
region at the time of visitation, and the occupation of the site is not contingent on seed production.

**Lithics**

The analysed sub sample of the lithic assemblage at Cathedral Cave comprised 1,460 artefacts (Table 8-61, Table 8-1). Specimens were analysed from RS, U1 and U6 at the back of the shelter and U4-8 at the front of the shelter. Of these 1,281 specimens were classified as flakes, flake fragments or retouched flakes. The assemblage was dominated by flakes and flake fragments (Table 8-61, Table 8-62). The stone artefacts were unevenly distributed by unit, with more than half the stone located in U6 and very little in the RS (Figure 8-41). The site contained seven hammerstones and 17 cores.

**Raw Materials**

The raw materials at the site were identified for each stone artefact then classified into four broad categories based on general siliceousness in order to analyse the impact of raw material properties on rates of taphonomic alteration. All layers were dominated by glassy and fine grained materials (Figure 8-44), with proportionally more glassy artefacts than either Rainbow Cave or Wanderer’s Cave (Figure 8-45).

**Heating of Stone**

Low frequencies of heat-modified lithic specimens were identified at the site, with a total of 169 specimens that were affected by heating (126 that were flakes, flaked pieces or retouched flakes). Cathedral Cave displayed the highest frequencies of heat affected artefacts (all classes), and highest range of types of modifications, of the three sites (Table 8-63, Table 8-64, Table 8-65, Table 8-67). The heated specimens show a range of diagnostic features consistent with both high-temperature fires (crazing and potlidding) and low-temperature fires (lustre, colour change). These data are consistent with the temperatures represented by the thermal modification identified in faunal specimens, and suggests incidental heating of lithic specimens either buried in sediments close to or directly beneath fires. Thermally modified stone has an uneven distribution across the levels of the site (Figure 8-46, Table 8-66).
Stone Trampling

Rates of 1) edge damage, and 2) transverse snapping were used to examine the potential impact of trampling on stone artefacts in the site. The analysis was restricted to flakes, flake fragments and retouched flakes to provide a controlled sample for the analysis (N = 1281).

Overall, there is a lower rate of edge damage at the site compared with Rainbow Cave and Wanderer’s Cave (Table 8-67). A total of 371 specimens (29.8%) showed positive evidence for edge damage. The attrition to the edges occurred throughout all levels of the deposit. There is no obvious pattern in the variation by level. There are some differences between the two units within the site (Figure 8-47). There is only modest variation between units, with edge damage ranging between 25-36%.

There are a number of factors that can affect the rate of edge damage 1) raw material type, 2) heating of stone, and 3) edge angle. These variables were examined in relation to complete flakes, flake fragments and retouched flakes to test whether they explain the higher rate of edge damage at the site, or contribute in a significant way to variations by level within the site. Glassy and fine-grained raw materials have a higher overall rate of edge damage at all three sites with at least 90% of the assemblage made on these types of material for all layers (Figure 8-48, Figure 8-44, Figure 8-42). Small differences may be occurring because of differences in the proportion of stone tools made of glassy materials but raw material composition cannot explain the lower overall rate of edge damage at the site, nor variations between layers.

The mean rate of edge damage on heated artefacts was 21.0% versus 29.7% on unheated artefacts indicating that heating has not caused an increase in rates of edge damage (Table 8-68). Overall, Cathedral Cave has a mean rate of heating of 8.2%, suggesting that any effect will be modest. Shallow edge angles make stone artefacts more vulnerable to edge damage (refer Chapter 5). There is some evidence that this has played a factor at Cathedral Cave: the mean edge angle for edge damaged artefacts was 18.2°, versus 23.3° for undamaged flakes (Table 8-69, Table 8-70). Cathedral Cave has the lowest mean edge angle of all three sites, indicating that the assemblage might be more vulnerable to edge damage overall (Table 8-61).

The overall rate of transverse snapping of flakes and flake fragments was 31% (N = 403), varying between 23-51% in layers with at least 20 artefacts (Figure 8-49, Table 8-67, Figure 8-50). Rates of transverse snapping increase with depth in U1 but there are no other notable
patterns by layer or unit (Figure 8-51). Rates of edge damage and rates of transverse snapping appear to be related when analysed by layer. Transverse snaps are more common on thin artefacts as measured by thickness, length/thickness ratios and platform thickness, matching results from technological analyses (Mitchell 1988) (Figure 8-43).

The large excavation layers and the effects of fluvial deposition make it difficult to assess whether stone artefacts have been sorted as the result of trampling. Artefact polish has been suggested to be related to trampling, however there are only three specimens that display polish and the sample is too small for further analysis.

**New Interpretations of Site Use**

At the end of the Beaton's excavation he made several statements about the occupation of the site, which were related to the environmental position and local resources available to inhabitants. Beaton argued that Cathedral Cave was intermittently occupied from 3,500 BP, and treated as a temporary shelter. This interpretation was supported especially by the stone tool assemblage, which indicated the use of the site as an outstation, rather than a central camp. The faunal assemblage reflected the complexity of the local environment, and very few of the remains were thought to have been deposited “naturally”. The site was not considered to be frequented by owls or other birds of prey (Beaton1991b:75). Species lists indicated a broad exploitation of local environments by human occupants. According to Beaton the floral record indicated the collection of large quantities of complete stroboli from plant populations 5-15 km away from the site by large numbers of people. The Macrozamia was argued to play an important role in occupation episodes. Beaton argued that Cathedral Cave was intermittently occupied from 3,500 BP, and treated as a temporary shelter. The uncertain depositional and chronological history of the site suggested several possibilities to Beaton: intermittent occupation; sediment loss at the front of the shelter; and shallow midden deposits across the floor of the site.

However the analysis presented here indicates a slightly different pattern. The taphonomic history of the site was characterised as 1) fluvial deposition, winnowing and movement, 2) canid use of the shelter throughout its formation but particularly since 2,300 BP, 3) and relatively low levels of human use of the site in between repeated fluvial events. This pattern of site occupation suggests that people were regularly in the region.
The periodicity and temporal length of the occupation events are difficult to gauge. Consideration of the temporal regularity of the occupation of Cathedral Cave in comparison to the other sites indicates a generally intermittent, transitory occupation of the site. The gaps in the return period of floods in the gorge at 560 years (as defined with the available data) indicate that site use was probably not determined, or constrained by these events (Mierendorf 1984; Turnbaugh 1978). This question can only be resolved through further archaeological testing of the site and collating further geomorphological data from the local region. What is clear is that this is a site with a stratigraphy defined by occupation events and a dramatic deposition of sediment by floods.

Also, a more taphonomically complicated picture has emerged concerning the argument for the human only deposition of faunal remains (Beaton 1991b:77). Fluvial events have been identified in the deposition and winnowing of faunal and botanical remains. In addition, both humans and canids have been involved in the selection, deposition and modification of several species in the site, and the identification of specific taphonomic agents on specific faunal species have been difficult, due to taphonomic overprinting. Analysis of the canid modification evidence from this period indicates that dogs were both modifying human caught large Macropods; bringing in, or modifying adult Petrogales and were depositing scat remains of juvenile Petrogales caught by individual dogs. The modification patterns on Petrogales are consistent with wild dogs or individual camp dogs, while the modification patterns on Macropods are consistent with either individual or pack hunting of dogs. Humans appear to have made use of local Macropod resources, while dogs appear to have made use of all local resources.

The faunal evidence supports the argument of human targeting of adult Petrogales and Macropods at the site. Beaton's argument for the hunting of large birds on post cranial elements (Beaton 1991b:81) cannot be supported as reanalysis of the previously identified "bird" specimens was accurately identified as rock wallaby (*P. pencillata*) femur and humeri portions, and not elements from birds at all. The species in the site, although they reflect local environmental conditions at the site, also reflect the ecological preferences of dingoes, either as camp dogs, wild dogs or both, at or near the time of human occupation events.

The Macrozamia evidence also paints an alternate view of Macrozamia use in the site. Based on MNI, the Macrozamia specimens do not support the argument for the collection of large quantities of complete stroboli from plant populations by large numbers of people. Thus, the claim that Macrozamia feasting played an integral role in occupation episodes cannot be
supported. Further work investigating the ecological evidence that repeated firing of populations creates large “bumper crops” of *M. moreii* seeds (Chapter 11) also do not provide support for this argument. Humans also appear to have collected relatively low quantities of available Macrozamia cones and seeds while foraging in the area around the site.
Chapter 9: Taphonomic Analysis of Rainbow Cave

...researchers are now quite prepared to acknowledge that [early] sites may be the product of many causes, and seem prepared to investigate what those causes might be (Hill 1989b:286).

...there is no guarantee that the complete set of processes involved in site formation can be isolated (Stern 1980)

Introduction

This chapter presents the results of the taphonomic analysis of Rainbow Cave. Questions of site formation and taphonomic processes were examined through a sedimentological analysis and a taphonomic analysis of faunal, macrobotanical and lithic remains. A 100% sample of faunal, Macrozamia and lithic remains were analysed from the excavated units 14S1W and 14N1W from Rainbow Cave. There were adequate sample sizes for each line of evidence, with a total of 2087 faunal specimens, 113 Macrozamia specimens and 502 lithic specimens (Table 9-1). The proportions of each specimen type were distributed differently between these two excavation units, with 14S1W containing most of the fauna and Macrozamia remains (73.69% and 63.71% respectively), while 14N1W contained the majority of the lithic evidence (66.33%). There are also differences in the temporal and spatial distributions of faunal, Macrozamia and lithic specimens between levels of the two excavation units.

Site Formation

As discussed in Chapter 3, several analyses of the sediments from the column sample from 14S1W were performed to characterise the site formation history of Rainbow Cave. These were: 1) range of grain sizes in the deposit, 2) vertical consistency of modal grain sizes, 3) mineral content of the deposit, 4) consideration of stratigraphic characteristics, and 5) analysis of chronology of site formation through age determinations and sediment build up rate.

Analysis of the sediments and consideration of stratigraphic characteristics indicate a sedimentary deposition history consisting of parent sandstone decomposition as a result of cavernous weathering processes (Beetson and Gray 1993) and additions of various forms of organic matter. The grain size range, modal grain size and mineral assemblage content are
consistent with a sedimentary deposit formed by deposition of quartz feldspar from Triassic sandstones typical of the CQH region (Beetson and Gray 1993; Webb 1992), and are also similar to other rockshelter deposits formed from sandstone disintegration (Hughes 1980, 1983).

The sediment analysis at Rainbow Cave indicates the deposition of sediment from a single and consistent source population. The grain size distribution (as indicated by analysis of the median, mode and mean) was clustered around medium sands in the upper deposit (0-30 cm), and coarser sands in the lower deposit (30-50 cm). Analysis of the graphic mean (Folk 1974, Chapter 3) roughly divides the deposit into two halves: between 30-50 cm depth the mean grain size was comprised of coarse sands, while the sediments became slightly finer in the upper 30 cm with a mean grain size of medium sand. Variations in the grain sizes in median and mean grain sizes through the deposit are evident. Sediments were skewed towards the coarse end of the fraction (-0.4-0.03 $\phi$), and the majority of levels were either coarse skewed or very coarse skewed, with only three levels (0-5 cm, 35-40 cm and 45-50 cm) displaying a near symmetrical distribution of grain sizes.

Both the clustering of the sediment sizes around these particular grain sizes, and the consistency of the distribution through the layers, is consistent with deposition of these grain sizes from the breakdown of parent sandstones of the Precipice, Evergreen and Hutton formations (Appendix Table A-2). The range of sediment sizes in the archaeological sediments (coarse to fine grained) are consistent with the range in the parent sandstone (coarse to fine grained), indicating this was the primary sediment source. The concentration of the sediment sizes around coarse and finer sizes is also consistent with other sandstone depositional sites in the region (Mulvaney and Joyce 1965, this study). There were no stratigraphic features suggesting periodic deposition by fluvial or aeolian processes, and the depositing medium was identified as gravity. The mineral content of the assemblage was comprised of quartz grains, feldspar and fine silts, which are consistent with the range of minerals of the parent lithology of the region (Baker et al. 1993; Beetson and Gray 1993:11, 26-27; Davies 1979; Mulvaney and Joyce 1965; Webb 1992).

**Chronology**

Beaton submitted one carbon sample from approximately 45 cm depth in basal strata in 14N1W that returned an age determination of 3,600 ± 100 BP for the initial occupation of the site (ANU 1521) (Beaton 1977). In order to create a more precise understanding of
sediment and site formation, an additional eight radiocarbon determinations were submitted, one sample from each 5 cm excavation level between 5-40 cm depth in 14S1W (Table 9-3). Large blocky pieces of charcoal were submitted from the column sample in 14S1W.

Although evidence for burrowing, erosional contact surfaces between strata, sediment induration, or other features indicating stratigraphic mixing was not observed at the time of excavation (Beaton 1991:11), several age inversions were identified in the sequence from 14S1W (Figure 9-1). The upper part of the deposit between 0-30 cm has two possible inversions (representing 83 years) while the lower half of the deposit between 30-45 cm appears to have one inversion (representing 174 years). The inversions cover different two-sigma ranges and lie outside the 95% confidence interval. This data may indicate significant time averaging in levels and over the depositional history in 14S1W, and is considered further below.

A second issue with the chronology of sedimentation and site occupation concerns considerable temporal differences in age determination obtained for similar depths in 14S1W and 14N1W (refer Table 9-3, Figure 9-1 Figure 9-2). The determination obtained by Beaton from 40 cm depth in 14N1W may indicate that the site was first occupied at 3,600 ± 100 BP (ANU-1521) (Beaton 1977, 1991a). However a date obtained from 35-40 cm depth in 14S1W returned a much younger date of 1,640 ± 60 BP (ANU-12133). The differences may indicate different site formation histories in the lower levels of these different units. If so, the chronologies of the two units are not comparable. The basal date for 14N1W is considered separately from the dated sequence obtained for 14S1W.

Rate of Sediment Formation

Due to dated inversions, changes in rate of sediment formation were unable to be constructed for each level of the site. However an overall rate of sediment deposition was constructed using the dated sequence from age determinations from 14S1W (Figure 9-2). Assuming sediment built up at a constant rate from 1,640 BP (1538 Cal BP), 1 cm of sediment took 41.01 years to form, or 0.024 cm of sediment deposition per year in 14S1W. If the older age determination of 3,600 BP (3982 Cal BP) is used, and assuming sediment built up at a constant rate, 88.48 years per centimetre of sediment formation, or 0.011 cm of sediment per year was deposited in 14S1W. The overall rate of site sandstone exfoliation and sediment formation are more rapid than those in Wanderer’s Cave, which was very slow at 116.75 y/cm or 0.008 cm/yr. Beaton noted fast sandstone weathering rates at Rainbow
Cave at the time of excavation (Beaton 1991a). Comparisons with Cathedral Cave are not valid due to frequent rapid sedimentation as a result of fluvial depositional events.

**Taphonomic Implications of Site Formation**

*Stratigraphic Integrity*

The date inversions, weak sediment consistence and low bulk density (refer Table 9-2) may indicate significant mixing of specimens has occurred within the Rainbow Cave deposit. The three major processes affecting the stratigraphic integrity of the site were 1) trampling, 2) sediment rate, and 3) low bulk density and weak sediment consistence. The effects of sediment rate were unable to be tested due to the several age inversions at the site. Bulk density estimates for the site characterised most levels as unconsolidated sediment, indicating that fracture, compression and distortion of the components as a result of sediment burial processes were unlikely; however the likelihood of vertical movement was increased. Issues of stratigraphic integrity and the extent of vertical movement were tested by 1) refitting of faunal specimens, 2) scatter plots of weight and width of lithic, faunal and macrobotanical components in each level (Peacock and Fant 2002), and 3) comparisons of the mean size (length, width and weight) of all specimens in each level of the site.

Both the refitting and the scatterplot data indicate that there was not extensive vertical movement of faunal specimens within the site. A total of 140 specimens were refitted in the two units at Rainbow Cave (Table 9-4). The majority of these were from 14S1W, where 115 specimens were refitted, in comparison to 25 specimens from 14N1W. A total of 30 conjoin sets were identified; the majority of conjoined elements were refitted from specimens within the same level. Only two conjoin sets were separated by more than 5 cm depth and both occurred in 14S1W; one set was refitted over 20 cm (four excavation units) between 10-35 cm and another set was refitted over 10 cm depth (two excavation units) between 15-30 cm depth. The percent of specimens that could be conjoined in each level ranged from 0.00-9.09% (Table 9-4), and the percent of specimens which were part of a conjoin ranged between 0-92.0% (Table 9-5). The majority of refits were confined to the upper 25 cm of 14N1W, while in 14S1W specimens were able to be conjoined in all levels except 45-50 cm and 35-40 cm depth with the highest number of refits occurring between 10-35 cm depth. The numbers of specimens in each conjoin set ranged from 2-23 (Table 9-4).
This pattern in the distribution of conjoined specimens was related to 1) sediment pH, 2) level of thermal modification of specimens in layers of the site, and 3) weathering stage. The relationship between conjoins and sediment rate was unable to be tested. The highest conjoin frequency occurred in the lower levels of 14S1W, where 92% (total $N = 25$) and 59% (total $N = 22$) of the specimens from these layers conjoined (refer Table 9-5 and Figure 9-3). However, this reflects the refitting of specimens which had broken in situ, possibly as a result of in situ chemical weathering in sediments with acidic pH of 5.0 (Table 9-6 Table 9-7). This pattern was also identified at Wanderer’s Cave. The most important constraint on conjoin success at the site was size reduction as a result of thermal modification, particularly calcination (Table 9-8, discussed below). The mean conjoin rate of faunal specimens was highest if they were slightly burnt (10.7%) and was lower if they were fully carbonized or were calcined to any extent (7.4% or lower). Overall, the conjoin data suggests there has been limited vertical movement in the deposit, and that some specimens have been broken in situ as a result of trampling, with pH and thermal modification affecting the specimen’s resistance to fracture.

Given specific taphonomic processes have affected the success of conjoins on faunal specimens in certain levels of the site, further checks on stratigraphic integrity using other lines of evidence were conducted. Scatter plots of weight and width of lithic, faunal and macrobotanical components were generated for each level (Peacock and Fant 2002).

Comparisons were made of the mean size (length, width and weight) of all specimens in each level. Lithic artefacts are distributed in a roughly normal distribution by layer (Figure 9-4). Experiments have indicated that such a distribution may indicate size-sorting caused by trampling (Gifford-Gonzalez et al. 1985). However, the scatterplot data for bone, Macrozamia, and lithics; and the mean size data for bone (Table 9-9), Macrozamia (Table 9-10) and lithics (Table 9-11, see also Table 9-12) indicated that there was not extensive movement of specimens in the site, and no patterning in size sorting was identified for Rainbow Cave. While the lithic specimens were not normally distributed when analysed by counts, a normal distribution in lithic specimens by weight was indicated. However, the distribution of the weight of artefacts in 14S1W is inconsistent with the patterning of lithic artefacts that has been identified in trampled deposits, which suggest that larger pieces should be present on the surface and smaller pieces beneath (Gifford-Gonzalez et al. 1985; Hughes and Lampert 1977; Nielsen 1991:483; Stockton 1973; Villa and Courtin 1983:267). The distribution of lithics with depth more likely reflects changes in human discard in the site. Overall, there are consistent patterns in size distributions in all levels, and while there
are some variations in size of some components and levels, these are related to specific taphonomic processes, rather than of trampling. These are discussed below.

**Differential Preservation**

At Rainbow Cave, there was limited evidence of specific post depositional and diagenetic processes. No specimens displayed evidence of manganese staining, root etching, insect modification, deformation or distortion, abrasion, sediment encrustation or mineralisation. Although modification from herbivores and insects were considered in the analysis, no positive identifications were made. There was also limited evidence of weathering on lithic artefacts ($N = 9$), which were probably related to recycling of raw materials on site.

However, several taphonomic processes controlled specimen preservation, identifiability and stratigraphic integrity at Rainbow Cave. The major taphonomic processes affecting both preservation and identifiability of organic specimens included: 1) weathering, 2) sediment pH, 3) thermal modification, particularly calcination, and 4) canid deletion and modification of elements. As was found at Wanderer’s Cave, all of these processes had important impacts on preservation and identifiability. As was found in all sites, the identification of faunal elements related to specimen size, and variations in specimen size were largely controlled by taphonomic factors.

**Weathering**

In contrast to Wanderer’s Cave, the majority of the faunal remains were comparatively heavily weathered at Rainbow Cave. A total of 760 faunal specimens (36.4%) formed the analysed sub sample, selected to be comparable with Behrensmeyer's (1978) experimental set (refer Chapter 4) (Table 9-13). Overall, different vertical distributions of the mean maximum weathering stage (MMWS) are evident between the two units. The entire range of weathering stages were represented in the assemblage (from weathering stage 0-5) (Figure 9-5; see also Figure 9-6 and Figure 9-7). The specimens at Rainbow Cave displayed a bimodal weathering distribution; with almost equal proportions of specimens having a maximum weathering stage (MWS) of 0 (39.8%) and a MWS of 5 (38.5%) (Figure 9-8).

There were also substantial differences in the MMWS for faunal specimens between the units; with a MMWS of 1.75 in 14N1W and 0.75 in 14S1W (Figure 9-9). The maximum weathering stages are consistently high for each level in both units, and overall, MMWs are
higher for all specimens in all levels of 14N1W in comparison to 14S1W (Figure 9-10). In both units weathering stages increase with depth, although the depth at which the MWS increases varies between the two units. In 14N1W the MWS increases early at 15 cm depth, and rose from 2 to a maximum of 5; while in 14S1W, the mean weathering stage between 15-30 cm depth ranges from 0.33 to 2.29, but the range increases to 2.65 to 5.00 between 30 and 55 cm depth. The distribution was closely related to evidence of burning.

Given the unique “U” shape distribution of the MWS at the site (Figure 9-8), further exploration of the weathering stage data was warranted. Following Behrensmeyer (1978, see also Lyman 1994; Martin 1999), weathering stages were further analysed using specific species as controls. The pattern identified above was confirmed by analysis of MWS in Petrogales and Macropods in the site: two similar species with similar bone structures to control for MWS variations by species and bone structure (as indicated by Behrensmeyer 1978, see also Lyman 1994) (Table 9-14). Specimens that could be identified as Macropus sp. were slightly more weathered in 14N1W, with a MMWS of 2.92 ($N=13$) in comparison to 14S1W, which had a MMWS of 2.33 ($N=33$). Specimens that could be identified as Petrogales also show the same pattern, however the results were much more striking, as Petrogales in 14N1W had a MMWS of 4 ($N=17$), in comparison to 14S1W where their MMWS was 1.13 ($N=61$). The results indicate that weathering processes were affecting all specimens in each unit and that there are consistent and striking differences in the MMWS between the two units.

$pH$

Although it is clear that weathering extents seem to be more extreme in the northern unit, it was not possible to examine weathering variations and $pH$ for 14S1W. This is because $pH$ was not collected for this unit at the time of excavation. Analysis indicated that significant variations in the vertical distribution of weathering stages occurred with depth in 14S1W (Table 9-15, see also Figure 9-11, Figure 9-12 and Figure 9-13). In 14S1W, almost all of the specimens that display the highest MMS at were contained in the lower 30-50 cm of the site, in levels with a $pH$ of 5.0 (MMWS of 2.14). The MMWS of specimens between 0-30 cm depth have a lower MMWS, ranging between 0.48-1.27 where sediment $pH$ was between 7.5 and 6.0. A reduction in the completeness of specimens was also identified in acidic sediments with a $pH$ of 5.0 (11% mean completeness, mean weight of 0.244 g), while specimens were generally more complete in more alkaline sediments (accepting that taphonomic factors also control variations in size). Weathering in the lower levels of the
deposit is suggestive of in situ weathering related to sediment acidity. The results for 14S1W may indicate that the pH in 14N1W may have been more acidic; faunal specimens in the northern pit are more heavily reduced (measured by estimated completeness) than in the south, even for the same weathering stage. Possible reasons for such a stark difference in acidity of sediments between the two units were further considered.

Thermal modification has been identified as a major factor in lowering weathering rates on faunal specimens and also increasing sediment pH through increasing ash content (Karkanus et al. 1999; Schiegl 1996). Results indicate there were considerable differences in pH between sediments of high ash content (pH 6.0-8.0) and those with potentially no ash content (pH 4.5-5) (indicated by relative burn extent in levels) (Figure 9-14, Figure 9-15, see also Figure 9-16, Figure 9-17). The hypothesis that bone was better preserved in sediments which had some evidence of burning (ash contributing to changes in pH of sediments) was tested by comparing the MWS of Petrogale elements in levels of the site between the pits, in those layers which had more burning extents (remnant hearths) to test if weathering extent was related to matrix properties.

Results of this analysis indicate that variations in the MMWS have occurred as a result of a combination of burning and pH. In addition, the MMWS data indicates 1) significant differences in preservation of faunal remains between the two units at the site, and 2) that MMWS was lower, and preservation generally better, in levels which have evidence of fires indicated by the presence of burnt specimens.

**pH and Burning**

Several analyses were performed in order to test the potential for the differential survivorship of both burnt and unburnt faunal specimens relative to pH (following Knight 1985). This was achieved by analysing 1) counts, 2) mean specimen completeness, and 3) the mean weight of burnt and unburnt specimens. Some preliminary tests of the potential differential preservation of carbonised and uncarbonised plant remains were also conducted.

At Rainbow Cave, as was identified at Wanderer’s Cave, there is evidence that both burnt and unburnt specimens were affected by the acidic sediments in the lower levels of the site. When measured by weight of burnt and unburnt specimens in the two pits, a reduction in the frequency of unburnt to burnt faunal specimens is indicated (e.g., 30-55 cm depth, pH 5.0) (Figure 9-18, Figure 9-19). A more marked reduction occurs in the preservation of both
burnt and unburnt specimens in 14N1W in comparison to 14S1W. An increase in survivorship, indicated by all variables, was identified between 0-30 cm depth where pH increased to 6.0-7.0. The reduced weights, counts and completeness of specimens in levels with acidic pH at the site (between 40-55 cm depth) is consistent with Knight’s study (1985), and suggests that differential preservation of burnt and unburnt specimens may have occurred due to pH, but that this may relate more to specimen size reduction from burning and weathering than pH (see below). Given these results, the potential preservation of burnt and unburnt Macrozamia specimens and pH was investigated. However results were difficult to interpret given small sample sizes.

Canid Modifications

The presence of canids at Rainbow Cave was indicated by faunal specimens, with direct evidence of canid gnawing and digestion (Table 9-16). Most of the evidence for canids in the site was in the form of specimens displaying evidence of digestive modification (17.5%, $N=361$), and roughly equal rates of specimens with both gnawing and digestion (3.0%, $N=52$), and canid gnawing (2.5%, $N=62$). All forms of canid modification were higher in 14S1W than 14N1W. Canid modified bone was distributed differently between the two units (Table 9-17; see also Figure 9-21, Figure 9-22). In 14N1W, digested bone was mostly in the upper 15 cm of the site, while at 14S1W the evidence occurred throughout all the levels, with the highest frequency between 10-15 cm and 20-25 cm depth. There were relatively low rates of gnawing evidence (less than 10%) in both units, the lowest in 14N1W and the highest in the two upper levels of 14N1W (surface and 0-5 cm) with 12% and 22% respectively, with gnawing evidence confined to the upper 30 cm in 14S1W. This was not a sample size issue in the bottom levels and therefore suggests that minimal canid activity in lower levels and in 14N1W.

The Faunal Component

At Rainbow Cave, the faunal analysis examined a total of 2087 faunal specimens (456.44 g), and was a 100% sample from both units excavated. The distribution of specimens varied by unit, more were contained in 14S1W, with a total of 1538 specimens (73.69%) and 549 specimens were present in 14N1W (26.30%) (Figures 9-23, Figure 9-24 and Figure 9-25). A total of 19 species were identified from Rainbow Cave, and 22.37% ($N=467$) were identified to species level. The range and frequency of species represented in Rainbow Cave is very similar to Wanderer’s Cave, reflecting the general environmental similarities of the
two sites. At Rainbow Cave, Petrogales and Macropods dominate the sample when analysed by MNI (Table 9-18) and NISP (Table 9-19). Rainbow Cave contains a lower frequency of *Macropus* sp., *Petrogale* sp., *Wallabia* sp. and *Trichosurus* sp. than Wanderer’s Cave. As discussed in Chapter 4, a significant portion of the unidentified specimens was the result of size reduction due to of singular and sequential taphonomic processes operating at the site.

Specimen identifiability varied between the excavated units. In 14N1W, 15.1% of specimens were identified as being from animals of medium size (Table 9-20), 4.9% were from animals with large body sizes, and 8.0% of specimens were from small animal body sizes, while most were not identifiable to body size (71.9%). In 14S1W, 27.9% of specimens were identified as from medium sized animals, 5.2% from animals of large body sizes, and 11.8% from smaller animals, while 55.1% were unable to be determined to animal body size. Generally the same patterns occur in age between the units (Table 9-21), where age is largely undetermined in both units (14N1W =93.4% unidentified, 14S1W =86.0%) with adults having a higher rate of identification in the southern unit (9.2%) compared to the northern unit (5.6%). Variations occurred between the units where rates of identification of animals of young age were higher in the southern unit (4.8%) in comparison to the northern (0.9%) and reflect canid activity (discussed below).

**Human Actors on the Faunal Assemblage**

Although humans are clearly indicated in site occupation events, the question of who was responsible for the deposition and modification of faunal remains is a significant issue that requires several types of analysis to disentangle. The most direct lines of evidence for human interaction with the faunal component include 1) butchery, 2) thermal modification evidence on species and elements, and 3) timing of thermal modification events in relation to bone discard.

**Faunal Butchery**

The most direct evidence for human association with deposited faunal specimens is the identification of butchery marks on faunal elements. However there was no evidence of human processing of the faunal assemblage (no cutmarks, loading points, evidence of force application (ribs, hackle marks). The lack of direct evidence for human butchery on faunal specimens consistent with 1) Solomon’s research which suggests that very few trace effects are left indicating human butchery (Solomon 1985), and 2) the operation of individual and
sequential taphonomic processes (discussed above) which have reduced specimen size and the identification of taphonomic effects. Experiments conducted in the forensic sciences indicate that butchery evidence is identifiable after significant thermal modification (deGruchy and Rodgers 2002; Hermann and Bennett 1999), supporting the inference that there may have been limited evidence for these events in the site. Insights into the human interaction with deposited faunas was attained through thermal modification data.

**Faunal Thermal Modification**

As discussed in Chapter 4, several taphonomic analyses were applied and variables considered in analysing the meaning of thermally modified bone. In contrast to Wanderer’s Cave, both the units at Rainbow Cave have a much greater proportion of calcined bone in comparison to the other sites (Table 9-22). Differences in the rates of thermal modification (Figure 9-26 see also Figure 9-27 and Figure 9-28) and vertical distribution are also evident between the two units (Figure 9-28). These differences may indicate variation through space and time concerning the duration, extent and temperature attained by fires between the units, or an increase in fresh bone on the surface of the site, or changes in discard and site clean up activities, rather than direct evidence of “cooking” at the site.

**Distribution**

Almost half of the faunal specimens at Rainbow Cave (47.1%, N= 984) displayed evidence of thermal modification (Figure 9-14). All levels displayed faunal specimens affected by heat. However both the number of specimens displaying evidence for thermal modification, and the distribution of thermal extents varied between the layers of the two units.

In 14S1W, approximately 65% or less of the faunal specimens displayed evidence of thermal modification and it was normally distributed with depth (Figure 9-26), with increase in the range of thermal modification extents evident between 30-35 cm depth. This is in contrast to the pattern in 14N1W, which displayed generally low rates and variations in burn extents in the lower 15 cm, and a large increase in the diversity of thermal modification extents in the upper levels.

The thermally modified specimens in 14N1W were almost entirely comprised of 100% calcined bone (80%), with equal proportions of slightly burnt and <50% calcined bone (7% each). The thermally modified specimens in 14S1W contained a greater range of burning...
extents, with only 50% of the bone 100% calcined, 30% fully carbonised, and 10% slightly burnt. Differences were also evident in the vertical distribution of thermal modification as 14S1W displayed a normal distribution in burning similar to Wanderer's Cave, while 14N1W the majority of evidence was confined to the upper 15 cm.

The extent of thermal modification on faunal specimens became clear when the evidence for burning modification over fracture surfaces (Table 9-23) and interior medullary cavities (Table 9-24) were analysed (see also Table 9-25). Very few specimens displayed modifications that indicate the specimen was burnt when it contained an outer covering of flesh. Results indicate that the majority of the thermal modification at the site occurred after edible meat was removed, while the bone still contained organic content. Almost all the bone at the site had both their fracture surfaces and medullary cavity was burnt. At Rainbow Cave, only 17 specimens (1.7%) did not have burning across the fracture surface, and only 14 specimens (1.4%) displayed burning on the outer cortical surface but did not have their interiors burnt. According to Gilchrist and Mytum (1986), the extent of calcination, the surface area of the bone that displays thermal modification, and the small size of the specimens, indicate that the majority of bone was fractured primarily after discard, as a result of proximity and length of time in fires at the cave, with heat promoting further fracture and thermal modification, rather than the bone necessarily being fractured prior to burning (Lyman 1994).

Following the methods outlined in Chapter 4, the proportion of carbonised to calcined specimens in Stiner et al.'s (1995) experimental sample were compared to Rainbow Cave. The analysis considered burning modification for each pit and the levels in each pit (Table 9-26), to investigate the timing of burning of the bone relative to discard. The data for 14S1W are consistent with Stiner et al.'s (1995) experiments and indicate that some buried bone was being incidentally thermally modified in the sediments beneath the fire, while the majority of the bones were being calcined while they were on the surface of the site. The pattern is slightly different in 14N1W, where most of the bone was thermally modified on the surface of the site directly beneath the fire, with less bone being thermally modified in the sediment. This pattern may be caused by three processes 1) fewer faunal specimens within the levels of 14N1W to become modified in sediments, 2) specimens remaining for long periods on the surface, and 3) issues of differential preservation.

Approximately equal ratios of calcined to carbonised specimens were found in only two levels of the site: 0-5 cm and 5-10 cm depth in 14S1W. The pattern in these upper levels is
consistent with experiments conducted in both archaeological and forensic disciplines to investigate the effects and meaning of thermal modification. This indicates that faunal specimens in the upper levels of 14S1W were burnt while they were within sediments, while the majority of the bones in all other levels were burnt to consistently high extents (calcined) for the majority of the site’s formation. According to the research of Stiner et al.’s (1995), Bennett (1999) and Gilchrist and Mytum (1986), this pattern of burning indicates that most bone was burnt as a result of direct proximity to a hearth. That some levels had more calcined bones than others was also identified in Wanderer’s Cave.

As was outlined for Wanderer’s Cave, the factors causing increases in the ratio of calcined to carbonised specimens could be further investigated using 1) sediment rates, and 2) differential loss of calcined to carbonised specimens to explain the reduction in calcination in these levels (and the selective removal of calcined bones from these levels). However, variations in sediment rate could not be analysed. The differential loss of incompletely calcined specimens is unlikely, as experiments have indicated that specimens incompletely burnt contain organic content and resist post depositional fragmentation. Thus, as was found at Wanderer’s Cave, the reduction in calcination extent of specimens in the upper two levels of 14S1W in the site may reflect real changes in fires: 1) lower intensity, 2) shorter duration, 3) reduction in the quantities of fresh bone on the surface of the deposit to be calcined as a result of hearth placement on top of fresh bones, or 4) change in disposal of faunal material into fireplaces.

The calcined to carbonised ratio data was examined for evidence of pit cooking of large animals (refer Chapter 4). This was investigated through analysis of 1) animal body size, 2) animal age, 3) the eight most commonly occurring species, and 4) among the 13 most commonly occurring elements for both units. Rates of burning were very consistent over all categories. Sample sizes were too small to consider element and species. Analysis of calcined to carbonised ratios for animal body size (Table 9-27), age (Table 9-28) and top eight species (Table 9-29) indicate no obvious pattern indicating cooking. For the site as a whole, the ratio of calcined to carbonised specimens was relatively constant, and only possums (T. vulpecula) were slightly more calcined than carbonised (a ratio of 1.17). This suggests that all specimens had an even chance of being burnt and no clear pattern concerning cooking practices were able to be identified using burn data. These results are very similar to those obtained from Wanderer’s Cave, and may indicate that any original modifications produced as a result of pit cooking were overprinted by later burning events, as experimental research indicates that incompletely carbonised bone can be further altered
in later thermal modification events. This may also help to explain the appearance of archaeological bone as incidentally burnt to high temperatures in most levels.

Overall, there is very little evidence for human association with the faunal remains when butchery or thermal modification is analysed. This pattern was very similar to that identified at Wanderer’s Cave, where thermal evidence suggested bones became modified as a result of lying on top of, or being interred in sediments close to the location of the hearth. Burning patterns with depth are clearly the result of modifications that occur as a result of processes of fire, rather than cooking. The pattern of burning at Rainbow Cave informs us about incidental burning, and variations in fire frequency, intensity and duration over time, with change in fire duration, frequency occurring in the upper level of the site.

Taphonomic Modification of Fauna by Canids

As outlined in Chapter 4, several methods were used to interpret and differentiate faunal modification patterns at Rainbow Cave, including 1) analysis of canid modified species at the site, and 2) body sizes of species. The analysis concentrated on Petrogales and Macropods to investigate primacy of human and canid involvement with these species at Rainbow Cave. Several analyses were performed, including 1) digestive and gnawing evidence on Petrogales and Macropods, 2) the age structure of the Petrogales and Macropods in Rainbow Cave, 3) differential representation of body regions, 4) differential representation of elements, 5) diagnostic regions on elements, and 6) element landmarks on Petrogales and Macropods.

The majority of the species in the CQH have been identified as prey species of dingoes. All species in the site overlap those that are identified in Australian ecological studies as being major prey items of dingoes. The analysis investigated the proportion of species represented by canid modification type and age category. These data suggest that dingoes have been responsible for significant portion of these animal size categories in the site. All forms of canid modification evidence were highest on animals of small body size (41.8%), followed by medium (33.6%) and large body sizes (25.2%) (Table 9-30). Sample sizes were too low to consider variations in canid modifications by species, except for Petrogales (Table 9-31).

The analysis then focused on patterns of canid modifications of Petrogales and Macropod specimens to investigate the primacy of human and canid involvement (Table 9-32, Table 9-33). A total of 38.1% of the sample identified as Petrogales were modified by dogs,
dominated by digestive modification (31.4%). A different pattern was identified with Macropod specimens, where 23.5% displayed gnawing modification and 14.3% displayed digestive modification. The majority of the evidence at the site was comprised of digestive modification, and this is suggestive of the use of the site as a den at various times in its formation.

The age structure of Petrogale and Macropod specimens were analysed over the site (Table 9-33, Table 9-34, Table 9-35, Table 9-36). At Rainbow Cave, there were almost equal proportions of young (13.8%) and adult Petrogales (19.7%), however the pattern was different for Macropods where there were fewer juveniles represented (6.1%) in comparison to adults (23.5%). The low rate of modification evidence of young Macropods may be a sample size issue (N = 6). The evidence for Petrogales is consistent with canid selectivity, while the evidence for Macropods is consistent with either human hunting or pack hunting by dingoes. More than 50% of juvenile and adult Petrogales displayed evidence consistent with canid modification (Table 9-36), with more than 40% of the evidence comprised of digestive modification. In contrast, 16.7% of juvenile Macropods and 34.8% of adult Macropods had evidence of canid modification (Table 9-36).

As was discussed in Chapter 4, anthropological accounts of butchery and dismemberment of Macropod carcasses should not result in differential representation of body region, or skeletal parts at the site. Ecological data also adds to this pattern as dogs are capable of carrying medium sized prey (6 kg females and juveniles) back to dens, and can reduce carcasses in den sites. Studies suggest that differences in the representation and survivability of body regions in canid modified carcasses are consistent enough to identify canid modification. This data suggests decreased representation of forearms, back, chest and feet, while increased representation of hindlimbs (Hudson 1993).

The differential preservation of body regions (head, chest, back, forelimbs, hindlimbs, feet and unknown) was analysed for Petrogales and Macropods at Rainbow Cave (Appendix Table A-7, and Table 9-37). Unfortunately the low sample sizes did not permit analysis of canid modification type by body region. However the overall patterns of representation across body regions is consistent with, and therefore suggestive of, extensive canid modification (David 1984; Solomon 1985). The overall pattern of survivorship at Rainbow Cave is consistent with those identified in studies. The proportional representation of all body regions of both Petrogales and Macropods at Rainbow Cave is very similar. The data from Rainbow Cave suggests decreased representation of the forearms, back, chest and feet.
relative to the hindlimbs (Hudson 1993). The differential representation of hindlimbs compared to all other body regions is consistent with Hudson (1993), and also with studies on Australian dingoes by Solomon (1985) and David (1984). These patterns are inconsistent with the natural disarticulation of Macropods ascertained by Reed (2001).

Small sample sizes limit the ability to compare patterns of canid modification between Petrogales and Macropods (Table 9-38). Overall the rate of modification is higher on Petrogales (38.8%) than Macropods (20.3%). There is a high rate of evidence for canid modification on phalanges for both categories, with 80.0% digestion for Macropods and 63.6% for Petrogales. Comparing the types of modification of tibias, where sample sizes are reasonable, differences in the patterns of modification probably related to differences in structural density. Petrogale tibias show a high rate of canid modification (19.7% digestion \((N = 11)\), and 14.3% gnawing \((N = 8)\)). In contrast, there is no evidence for digestion on Macropods tibias, with only 4.5% \((N = 1)\) showing gnawing modification.

Evidence of digestion was identified in all levels of 14S1W, but increases dramatically in the upper 15 cm of the site. There is a similar increase in the upper 10 cm in 14N1W. Digestive data was highest for juvenile Petrogales, and lowest for Macropods. Of the Petrogales, dog modification occurs in the upper 30 cm, split evenly between juvenile and adult Petrogales. This is not a natural distribution – and indicates selective predation of juveniles which is characteristic of canid predation. This suggests that most of the digestion at the site indicates dog only prey selection. The range of elements represented in canid scats was also consistent with canid patterns of carcass reduction. The digestive pattern in all sites suggests a relatively late increase in the dog occupation of sites and possible territorial marking.

Analysis of the gnawing data suggests significant modification by canids of both adult and juvenile Petrogale body regions and elements that are entirely consistent with available ecological data and structural density. The gnawing data suggests two things: 1) low rates of gnawing in these levels of the site indicate dogs are not bringing in kills themselves to the site, and 2) given that the highest evidence for gnawing modification is contained on Macropods, and is temporally and spatially associated with human activities, this may indicate canids are gnawing the remains of humanly caught Macropods. Both the canid data and burning data suggest that people were going to the site on a consistent but limited basis during the time when most of the burning and Macropod deposition occurs in the upper 30 cm (1712-547 Cal BP). The activities of dogs and humans are both directly and indirectly associated at the site.
Rodents on Bone

Rodents have not been a significant taphonomic factor at Rainbow Cave (Table 9-40). Only six (0.3%) faunal elements displayed surface modifications consistent with gnawing by rodents, which was the lowest rate of rodent modification on faunal specimens for the three sites. There are good reasons why rodents are probably not a substantial modifying or contributing factor at Rainbow Cave: the site is far removed from food sources of rodents, the site is relatively difficult to reach. Basic gnawing patterns were consistent with those identified from Cathedral Cave, and reflect general patterns of opportunistic gnawing of faunal elements.

In summary, rodents appear to have had access to fresh faunal specimens, as four of the six rodent gnawed specimens were unweathered. The gnawing occurred over an average 25% of the surface of the midshafts of the femur, humerus and fibula, of Macropus, Petrogale sp. and unidentified species. These rodent gnawed specimens were also burnt to varying extents, although it is difficult to know if the gnawing occurred prior to or post burning of the elements.

There is more evidence for gnawing on Macrozamia seeds, suggesting incidental rodent gnawing on faunal elements at times when rodents had gone to Rainbow Cave to “security eat” Macrozamia. Rodents have the highest rates of gnawing of both faunal and Macrozamia specimens in the surface layer of the site, and gnawing of both Macrozamia seeds and faunal elements was low in each level of the site. That rodents lived near to or within the site is also supported by faunal elements of rodent species identified from the site, in the levels associated with rodent gnawed faunal and Macrozamia specimens.

The Macrozamia Component

There is some uncertainty regarding the provenance of the material available for analysis, particularly in specimens from the upper 15 cm of the site. Macrozamia analysed here were derived from 0-10 cm depth in 14N1W and 10-35 cm depth in 14S1W. It is not clear from the available records if this reflects the absence of Macrozamia from many levels of both units of the site, missing materials or the accidental amalgamation of materials from the two units at some time in the past. However, the distribution of Macrozamia remains generally matches the distribution of human activities for both pits. As a result of the possible
conflation of specimens from the upper levels of the site, the Macrozamia were considered to be from the site as a whole.

Even given the above problems, there were very few Macrozamia specimens present at Rainbow Cave in comparison to the other two sites (Table 9-50). A total of 113 available specimens formed a 100% sample, and included seed shell (sclerotesta) and kernel (testa). Macrozamia specimens were distributed in small quantities between the surface and 35 cm depth (Figure 9-31), and the number of specimens in each level was below 25, ranging between 5 and 23. The highest count was 23 specimens in the surface level, and 17 specimens in levels 0-5, 15-20, and 20-25 while all other levels had less than 13 specimens. A generally consistent distribution of specimen kinds, including fragments of either micropylar or attachment ends (“shell”) and non diagnostic shell “body” portions, is evident throughout the levels (Figure 9-32, Table 9-41), with one kernel identified from 15-20 cm depth.

Specimen sizes as measured by mean completeness of shell, completeness of diagnostic ends, weight, length or thickness do not vary considerably over time (Table 9-10), and suggests consistent taphonomic processes controlling specimen size. The mean completeness of specimens was consistent between the sites (Table 9-42) at around 17% and (compared with Cathedral Cave (17%) and Wanderer’s Cave (16%)). The mean end completeness of either end at Rainbow Cave is more similar to Cathedral Cave than to Wanderer’s Cave. This may be explained by different carbonisation extents in the Macrozamia assemblage in Wanderers Cave in comparison to the other two sites. In all but two levels there are more specimens with parts of the diagnostic ends than specimens without these ends. This indicates that in most levels, counts of MNI are not influenced by variations in specimen portions in levels (discussed further below), and that humans were the primary agents of modification at the site.

Non-Human Agents of Macrozamia Modification

Although several animals were identified as collectors, transporters and predators of seeds in Macrozamia communities, only rodents were identified as important agents. Rodents are likely to have been responsible for transport and deposition of the seeds to the site. A total of 27 specimens had evidence of rodents gnawing off the outer sarcotesta (flesh) of fresh specimens at the site but did not breach the shell (Table 9-43, Table 9-44). Sample sizes are low when considering the distribution of gnawed sarcotesta by level (Figure 9-33), with less
than five specimens in each level, except for the surface level which contained 12 specimens with gnawing evidence. Rodent marks occurred both on specimens that displayed evidence of weathering (Table 9-45), and those that were fresh at the time of collection. Overall, only 23% of the specimens could have been transported to the site by rodents only, indicated by gnawing of the flesh. However rodents were not heavily involved in opening the specimens as only one specimen had unambiguous evidence for opening by rodent only, and one opened by insects only. No specimens were identified as being opened by both rodents and humans, or insects and humans (Table 9-43). Inferences concerning rodent gnaw patterns and the use of Macrozamia plants and site by both humans and rodents is discussed below.

Human Evidence for Macrozamia Processing

Several features of the Macrozamia assemblage suggest the majority of the seeds were opened as the result of human force. All fracture patterns analysed for Rainbow Cave were consistent with those generated in the experimental set. Direct evidence of human processing of the Macrozamia specimens included 1) evidence of fracture as a result of human PFA including specimen shape, 2) evidence of direct PFA to the specimens, and 3) thermal alteration of specimens consistent with human cooking of Macrozamia.

Evidence of Fracture Techniques

The range of specimen shapes (transverse, longitudinal and both) and body specimens was similar to that obtained in the experimental trials for Macrozamia processing (Table 9-46). Approximately 35% (N = 40) of the Macrozamia specimens displayed direct evidence of fracture features on shells indicative of human application of force during processing activities (e.g., ringeracks, hair fractures) (Table 9-47). An increased use of force may be indicated from the increased frequency and relative proportion of longitudinal and transversely shaped specimens (redirection fractures of Chapter 7) and non diagnostic (body specimens) at Rainbow Cave in comparison to other sites and the experimental set. Although 65% of the assemblage did not display evidence of human force, however a considerable proportion of the experimental set also did not display direct evidence of PFA. It is still probable that these specimens were the result of human processing.

Analysis of the estimated completeness of specimen ends and ringerack position suggests humans opened the seeds by striking their sides. When the patterns for the site as a whole are considered (although the sample size is still low), side opening of the seeds is suggested,
with 18% of the specimens ($N = 15$) having a complete end (which indicates side striking), and only 4% ($N = 2$) of specimens with portion of both diagnostic ends, which indicates end striking (Table 9-48). The interpretation of side striking is also supported by the presence of ringcracks on the side of specimens (14.2%) in contrast to ringcracks on the ends of specimens (0%). The patterns match those in the experimental data set. The method of opening the shell remains consistent though time at the site, with minor variations caused by thermal modification and force variables affecting the representation of both ends and ringcracks as indicated by experimental data (Chapter 7).

**Evidence for Thermal Processing**

At Rainbow Cave, the majority of specimens in all layers except the surface show evidence of thermal alteration consistent with temperatures used by humans to process specimens. A total of 58.4% ($N = 66$) of specimens were heated to 200 °C and 16.8% ($N = 19$) were carbonised (Table 9-49, Figure 9-34). While there is an absence of carbonised specimens in some levels of the site, the pattern for both burn extent and distribution closely matches that obtained for the faunal specimens. The specimens at Rainbow Cave show a higher frequency of carbonised specimens in comparison to Cathedral and Wanderer’s Caves, and although higher levels of carbonisation exist, specimen sizes do not appear to have been reduced in relation to carbonisation, as was indicated at Wanderer’s Cave. This may suggest specimen reduction was related to both carbonisation extent and trampling at Wanderer’s Cave, and suggests for Rainbow Cave, that thermal processing or preservation processes do not bias preservation and estimates of MNI.

**Age of Seed at Processing Time**

A total of 10 specimens of the 113 (10.0%) had traces of sarcotesta on seed shells (Figure 9-35, Table 9-50). The majority of these were located between 20-25 cm ($N = 8$), with one specimen each in the surface level and 15-20 cm. The weathered specimens ($N = 27$) were distributed unevenly in levels of the site (Figure 9-36).

Overall, the majority of the specimens were non diagnostic body fragments. These were produced as a result of rebound forces on the anvil or subsequent breakage as a result of post depositional processes. However these issues did not have an impact on the ability to make interpretations of the material, and a number of statements can be made concerning the human use of Macrozamia specimens at the site.
There are two noteworthy features of the Macrozamia assemblage 1) the density of Macrozamia is considerably less than those proposed by Beaton (1977, 1991a) for the site (c. 400-600 specimens per m$^3$), and 2) the estimated MNI's are extremely low. Using the estimations of overall specimen completeness returns an estimate of approximately 20 seeds for the entire site (discussed in further detail in Chapter 11). This calculation allows the analyst to use all specimens from the site in estimates of MNI. A total of 65 specimens were able to be used in MNI calculations based on estimates of end completeness, and suggest an MNI of 23 seeds when estimates of completeness of the micropylar ends are tallied; or an MNI of 15 seeds when estimates of the completeness of the attachment end are tallied. Based on the MNI using specimen completeness, there is an average of less than four seeds in each level of the site, or less than six seeds when calculations using the estimated percent completeness of diagnostic ends (attachment or micropylar). Even if a more generous estimate of MNI using NISP was used, 113 nuts would be indicated, representing 1/3 of the seeds from one cone produced by an adult M. moreii. Finally, the evidence for the onset of use/discard is considerably more recent at Rainbow Cave at 1,640 ± 60 BP (ANU-12133) (1686-1516 Cal BP) than other sites in the region.

A range of inferences can also be made using ecological data concerning insect attrition of seeds in Rainbow Cave. At Rainbow Cave there is little evidence of attrition of shells from insect pollenisation activity, a pattern that was also identified at Wanderer’s Cave, but was not indicated at Cathedral Cave. Isolated populations of Macrozamia are unable draw as many insect pollinators and seeds display less damage by insect pollinators. The lack of insect activity suggests that seeds, either collected from entire cones or off the ground surface after breaking up, were collected from plants in isolated populations. This suggests the low density of Macrozamia plants around Rainbow Cave over the last 2,000 years of Macrozamia deposition.

Several inferences can be made concerning the human use of Macrozamia plants based on the age of the seeds at the time of processing and the patterns of rodent gnawing of the outer sarcotesta. The rodent gnawing of seeds is also informative of coning frequency of the population over the last 2,000 years of human use of Macrozamia plots and the site and region generally. The low frequency of specimens with breached shells is consistent with rodent gnawing of seeds in the local environment when they still had flesh attached to the seed within a few months of cone disintegration in the population. Although the frequency of rodent gnawing of specimens in the site is relatively high ($N = 27$ of $118$), a
comparatively low density is suggested in archaeological populations in comparison to modern ecological data.

Ecological data suggests rats are attracted to large Macrozamia populations with high coning frequencies (Ballardie and Whelan 1986:104, see also Chapter 6). High rates of gnawing the flesh are reflected in these populations even when rats move seeds to security feed. The gnawing rates in Rainbow Cave probably reflects the low coning frequency around Rainbow Cave, and possibly also reflects the generally low presence of rodents around the site, as Burbage and Whelan (1982:63) found that dispersal is not affected by the presence of the outer flesh on the seeds. Rodent data indicates seeds were not always available in the environment for human collection, and may suggest irregular seed production in non-masting plots.

Weathering data indicates that seeds were collected once fallen from cones, several months after cone production. There are variations in the weathering rates displayed by specimens in the site through time. Almost 70% of Macrozamia specimens between 25-30 cm were weathered, indicating that humans were collecting aged seeds at this time (Figure 9-36). Ecological studies provide a “terminus ante quem” for this event at approximately 1-2 years after the last coning event (Ballardie and Whelan 1986, refer Chapter 6). The general lack of fresh seeds in that level also indicates that coning was not occurring at this time, and humans were collecting available nuts in the environment opportunistically. Rodent marks were also low in this level, supporting this position. In all other levels of the site, the proportion of weathering is 30%, which indicates the collection of aged nuts beneath parent plants, and possible collection of seeds from disintegrating cones on the plants.

These ecological data are suggestive of intermittent, opportunistic “mundane” use of Macrozamia by humans. The available archaeological and ecological data does not support Beaton’s model of Macrozamia use. Macrozamia may not have occurred in high densities at the site in the past; were probably patchier in distribution; seed production may have been sporadic and limited. This latter point especially, does not support the idea of periodic increases in seed production by natural or humanly generated mass coning events. I further re-examine prior models of human use of Macrozamia in the CQH in the light of ecological, archaeological and taphonomic data in Chapter 11.
Lithics

Overview of the Assemblage

The lithic assemblage at Rainbow Cave was comprised of 502 artefacts (Table 9-51). Of these, 370 specimens were classified as flakes, flake fragments or retouched flakes. Overall, the assemblage was dominated by flakes and flake fragments. The site contained two hammerstones and three cores (Table 9-52).

Raw Materials

Raw material type was identified for each stone artefact then classified into four broad categories based on general siliceousness and grain-size in order to analyse the impact of raw material properties on rates of taphonomic alteration. The majority of artefacts were created on glassy and fine-grained materials, comprising 70% or more of most levels of the site (Figure 9-37).

Microdebitage

The presence of microdebitage indicates that people were knapping in the site. A total of four microdebitage flakes were identified from the -2 and -1 4 from the sediment analysis. Unfortunately spatial and temporal patterns concerning on site knapping were not able to be investigated as sediment samples were excavated from only one excavated unit (14S1W). Two specimens were identified from 20-25 cm depth, and one specimen was identified from both 40-45 cm and 45-40 cm depth. Overall, there is little evidence, from the sediments of 14S1W, that on-site knapping occurred at Rainbow Cave.

Heating of Stone

Low frequencies of heat modified lithic specimens were identified at the site, with a total of 28 specimens that were affected by heating (11 that were flakes, flaked pieces or retouched flakes) (Figure 9-38). The heated specimens show a range of diagnostic features consistent with both high-temperature fires (crazing and potlidding) and low-temperature fires (lustre and colour change). These data are consistent with the thermal modification identified in faunal specimens, and suggests incidental thermal modification.
Stone Trampling

Rates of 1) edge damage, and 2) transverse snapping were used to examine the potential impact of trampling on stone artefacts in the site. The analysis was restricted to flakes, flake fragments and retouched flakes to provide a controlled sample for the analysis (N = 370).

A total of 128 specimens (34.6%) of the 370 analysed artefacts showed positive evidence for edge damage (Table 9-53, Table 9-54). Attrition to the margins occurred throughout all levels of the deposit (Table 9-55). No pattern was identified in the distribution of edge damage by level. However there are some differences between the two units within the site, with the average rate of edge damage in 14N1W was 29.3%, compared with 44.5% for 14S1W (Table 9-56).

As discussed in Chapter 5, there are a number of factors that can affect the rate of edge damage including 1) raw material type, 2) heating of stone, and 3) edge angle. These variables were examined in relation to complete flakes, flake fragments and retouched flakes to test whether they explain the higher rate of edge damage at the site, or contribute to variations by level within the site.

Results indicate that glassy and fine-grained raw materials have a higher overall rate of edge damage at all three sites (Figure 9-39). The proportion of the assemblage created on these materials remains relatively constant throughout the history of the site, varying between 70% and 100% by layer (Table 9-55). However, raw material difference cannot explain the overall higher rate of edge damage at the site: the overall breakdown of raw material is very similar to Wanderer’s Cave and slightly more coarse-grained than Cathedral Cave.

Tests were undertaken to determine if heating was responsible for the rate of edge damage at the site. The rate of edge damage on heated artefacts was 54.5% versus 34.0% on unheated artefacts (Table 9-57). However, the sample size of heated artefacts is small (N = 11) and heating is unlikely to be contributing to the overall rate of edge damage at the site. At Rainbow Cave, there was no clear association between edge damage and heating. Overall, Rainbow Cave has a rate of heating of 3.0% (11 of 370), compared with 5.9% (11 of 187) for Wanderer’s Cave and 8.2% (105 of 1281) for Cathedral Cave. Even if thermal modification did make stone more vulnerable to edge damage, heating cannot explain the considerable differences in the proportion of artefacts with edge damage between the sites.
Shallower edge angles make stone artefacts more vulnerable to edge damage (Table 9-54). There is some evidence that this has been a factor at Rainbow Cave: the mean edge angle for edge damaged artefacts was 23.1°, versus 28.4° for undamaged flakes. The site has the highest mean edge angle of the analysed sites, which may reduce the overall rate of edge damage at the site in comparison to others. This may also mean that edge damage is not an adequate indicator of trampling damage at the site, with under-representation of the impact of trampling or equivalent processes. It is also unlikely to explain the differences between the two units at the site: 14N1W has a mean edge angle of 25.9° versus 27.8° for 14S1W (Table 9-58).

At Rainbow Cave, the overall rate of transverse snapping of flakes and flake fragments was 17% \((N = 63)\) (Table 9-53, Table 9-54). Variations occurred between levels, varying between 9% and 24% in layers with at least 20 artefacts (Figure 9-41). There is no clear relationship between raw material and rates of transverse snapping (Figure 9-40). Analysis of shape and size attributes suggest that the rate of transverse snapping appears to relate primarily to the thickness of the artefacts, with thinner artefacts more likely to be snapped, and the overall rate of trampling. Unit 14S1W has a higher rate of transverse snapping but a higher mean thickness, indicting that differences in size and shape will have reduced the rate of edge damage in this unit rather than increased it (Table 9-56).

Overall, it is likely that edge damage and transverse snaps provide a general indicator of the rates of trampling at the site. Combining the overall trends for snapping and edge damage, the evidence is suggestive of a high rate of trampling in the upper 10-20 cm in both units.

**Interpretations of Site Use**

Previous interpretations of Rainbow Cave can be considered in relation to the archaeological analyses identified here. At the end of Beaton’s excavation of the site, he made several statements concerning the occupation of the site. The site itself is difficult to access, and it was also difficult to access local watersources. Stone tools were manufactured at the site, although this comprises a small component of the cultural material. Local marsupial fauna represented in the deposits but in small quantities, as most of the organic remains in the sites were burnt wood and burnt and unburnt remains of Macrozamia seeds, which were “the most abundant cultural materials at the site” distributed throughout the deposit and in amounts which suggest they were important resources at the site (Beaton 1991a:11, 31). Chemical loss of specimens at the base of the site was suggested, and noted that bone
appeared to be well preserved in the upper levels, but friable in the lower levels (Beaton 1991a:15).

The taphonomic history of the site was characterised as 1) different activities performed in one end of the shelter (14S1W) in comparison to the other, 2) potential for low visitation prior to 2,000 BP, and 3) the occupation of the site by humans and dogs, either independently or together after c. 2,000 BP. The majority of Beaton’s claims for the site are difficult to disagree with, except the interpretation and arguments concerning the Macrozamia component. Rainbow Cave has the lowest number of Macrozamia specimens, and the lowest density, and lowest MNI of the three sites, and lowest count of any of the archaeological components at the site. These four factors make Beaton’s claim that Macrozamia were “the most abundant cultural materials at the site” and “important resources at the site” somewhat overstated. Macrozamia appears to have contributed a small proportion of the subsistence base during occupation of the site, collected from low density, local populations in non-masting periods, with the collection of both weathered and fresh seeds when they are available in the environment.

It is clear that taphonomic processes have shaped the content and distribution of archaeological materials in the site, however it is still possible to make inferences about human behaviours at the site.

Taphonomic processes generally divide the occupational record at Rainbow Cave into two halves: between 0-30 cm and 30-50 cm depth. Within the lower occupation levels, between 30-50 cm depth (1712-3982 Cal BP), the intensity of occupation appears to be relatively low as a result of preservational biases. Significant taphonomic modification of the faunal component occurred due to acidic sediment pH. In addition, very low levels of canid only occupation, and human and canid occupation of the site are represented, and it is difficult to identify whether the two agents were associated or independent of each other at this time.

There is better preservation of evidence for both human occupation and canid occupation in the upper portion of the site, between 0-30 cm depth (prior to 1065 Cal BP). This is largely the result of an increase in the pH of the site, in part associated with the changes to site matrix acidity as a result of thermal modification contributing high ash content to the sediments enclosing organic materials, which resulted in better preservation and identification of, taphonomic actors and effects. During this period canids and humans are the main taphonomic signatures at the site.
Thermal modification data suggests the incidental thermal modification of bone already deposited in sediments, or underneath fire hearths, at reoccupation events. Extensive thermal overprinting of faunal specimens is indicated at the site. There does seem to be a genuine difference in hearth placement between units, and the focussed fires in 14S1W in comparison to 14N1W.

It was difficult to identify direct association of humans with the faunal assemblage. Faunal species identified during this period generally reflect the range available in the local environment. The species represented are a reflection of prey selection by both humans and canids. However, the high rates of thermal modification, lack of butchery evidence, and dual patterning of canids and human signatures, combine to modify the archaeological component to such an extent that it was difficult to identify human interaction with the local faunas.

Dogs were also implicated as a significant taphonomic factor in the upper 30 cm of the site, reflected in the deposition of scat bone material to the site. Dog gnawing and digestion evidence appears to be loosely associated with human activities at the site, and it is possible that dogs were using the site at the same time humans were. At the same time, analysis of the scat material suggested that wild dogs, or dogs which had become disassociated from human groups, had consistently targeted Petrogales, as well as other small animals. Further research is required to more clearly differentiate the actions of dogs, and association with humans.
Chapter 10: Taphonomic Analysis of Wanderer’s Cave

Introduction

This chapter presents the results of the taphonomic analysis of Wanderer’s Cave. Questions of site formation and taphonomic processes were examined through sedimentological analysis and taphonomic analysis of faunal, macrobotanical and lithic remains. A 100% sample of faunal, Macrozamia and lithic remains were analysed from unit 3N4E, the only unit excavated from the site. There were adequate sample sizes for each line of evidence, with a total of 1893 faunal specimens, 1514 Macrozamia specimens and 261 lithic specimens (Table 10-1). The proportions of each specimen type were distributed differently through excavated levels.

Site Formation

Analysis of the sediments and consideration of stratigraphic characteristics indicate a sedimentary depositional history consisting of parent sandstone decomposition as a result of cavernous weathering processes (Beetson and Gray 1993) and additions of various forms of organic matter. The grain size range, modal grain size and mineral assemblage content are consistent with a sedimentary deposit formed by deposition of quartz feldspar from Triassic sandstones typical of the CQH region (Beetson and Gray 1993; Webb 1992), and are also consistent with other rockshelter deposits formed from sandstone disintegration (Hughes 1980, 1983).

The sediment analysis at Wanderer’s Cave indicates the deposition of sediment from a single and consistent source population. The size distribution of the sediments in Wanderer’s Cave was determined by calculating the graphic mean of the grain size (Table 10-2) (Folk 1974). The sediments were much coarser than those at Rainbow Cave, and were consistently coarse in all levels. Some slight variations occurred in some layers regarding the mode of the sediments, which changed from medium sands in the upper 20 cm to coarser sands between 20-45 cm depth. Beaton noted the coarseness of the sediment in these lower levels at the time of excavation (Beaton, unpublished fieldnotes). Variations in the skewness of the...
distribution of sediments were identified with depth at Wanderer’s Cave, with six levels near symmetrical, two coarse skewed and one fine skewed.

The range of sediment grain sizes at Wanderer’s Cave ranged between coarse sands and silts, and is consistent with deposition of these grain sizes from the breakdown of parent sandstones of the Precipice, Evergreen and Hutton formations (coarse to fine sands and silts), suggesting that this was the primary sediment source (Appendix Table A-2). Coarse sediments (indicated by mode and mean sediment sizes) at the site indicate the deposition of coarser sediments, which in this context, indicate deposition by gravity. There were no stratigraphic features suggesting periodic deposition by fluvial or mass wasting processes. The mineral content of the assemblage was comprised of quartz grains, feldspar and fine silts which are consistent with the range of minerals of the parent lithology of the region (Baker et al. 1993; Beetson and Gray 1993:11, 26-27; Davies 1979; Mulvaney and Joyce 1965; Webb 1992).

A marked shift in the percent of organics and the percent of roofall between 20-25 cm effectively divides the deposit in two portions (Table 10-2). The sediments between 30-45 cm depth were characterised by high roofall, low organic content and neutral to acidic pH; while the upper 30 cm of the deposit contained less roofall, and a higher organic component with a mean pH of 8.0.

Age Determinations

Beaton obtained two age determinations for the site (Table 10-3, Figure 10-1). A determination from approximately 37 cm depth indicated that initial occupation began prior to 4,320 ± 80 BP (ANU-1522), and a determination from approximately 7 cm depth indicated that occupation ceased sometime after 820 ± 70 BP (ANU-1539) (Beaton 1977, 1991a). In order to create a more detailed understanding of sediment and site formation, an additional four radiocarbon determinations were obtained for the site. Carbon samples were obtained from each level of the column sample between 5-40 cm depth (refer Chapter 3). No inversions were obtained for the site. Small quantities of charcoal between 40-50 cm depth were unable to be submitted for dating at the time of this research, and as a result the determination of 4,320 ± 80 BP (5021 Cal BP) may not directly indicate initial timing of sediment and artefact deposition in the shelter. Samples from the upper 5 cm of the deposit were unable to be submitted for age determination at the time of this research, and the
determination of 820 ± 70 BP does not represent the cessation of human visitation to the shelter.

Rate of Sediment Formation

The rate of site/sediment formation was slow, averaging 116.75 years for every centimetre of matrix formed in the site, or 0.008 cm per year over the entire site (Figure 10-2). Three general rates of formation of the sediment are indicated in the age depth curve. The lower (30-40 cm) and upper levels of the deposit (0-10 cm) have among the highest rates of sediment formation at the site, taking between 19 and 94 years to accumulate 1 cm of sediment (Table 10-2). This is in marked contrast to the deposit between 10-15 cm and 25-30 cm, each of which took approximately 130 years to form each centimetre. The slowest rates of sediment formation occurred between 15-25 cm depth, ranging between 270-283 years per centimetre. The taphonomic implications of the variations in the rate of sediment formation at the site are discussed further below.

Taphonomic Processes in Site Formation

Vertical Movement

The weak sediment consistence, low bulk density and low sedimentation rates (Table 10-2) at Wanderer’s Cave indicated that stratigraphic (vertical) mixing might have occurred in the deposit. Issues of stratigraphic integrity and the extent of vertical movement were assessed through 1) refitting of faunal specimens, 2) scatter plots of weight, width of lithic, faunal and macrobotanical components in each level of the site (Peacock and Fant 2002), and 3) comparison of the mean size (length, width, weight) of all specimens in each level of the site.

Both the refitting and scatterplot data indicate that there was not extensive vertical movement of faunal specimens in the site. A total of 144 faunal specimens were refitted at Wanderer’s Cave (Table 10-4, Table 10-5, Figure 10-3), almost all of which (N = 138, 95%) occurred within a level. Only two conjoin sets were refitted from fragments that were separated by one-excavation level, or 5 cm of sediment. The percent of specimens in each level that were able to be conjoined was fairly constant through levels, ranging from 1.13-2.89% with the exception of 35-40 cm and 40-45 cm depth, where the percent conjoined
increased to 3.41% and 7.41%. The percent of specimens which were part of a conjoin set ranged between 4% and 14%.

This pattern in the distribution of conjoined specimens was analysed by considering 1) sediment rates, 2) sediment pH, and 3) the level of thermal modification of specimens in layers of the site. The highest rates of conjoin refitting occurred in the lower 35-45 cm. The high conjoin rates are a result of the operation of three taphonomic processes: lack of thermal modification, acidic pH and slow sediment rates. Thermal modification has been found to significantly reduce the size of specimens (discussed further below). The excavated levels of 35 to 45 cm had the highest frequency of unburnt specimens (Figure 10-4, see also Figures 10-5, Figure 10-6). Increased fracture of chemically modified specimens occurred in the lower deposits (Table 10-6, Table 10-7), while fast sediment formation rates (19 y/cm) acted to “cap” the level from further trampling modification. In other levels of the site, conjoin success was also found to vary with the extent of thermal modification (Table 10-8), where conjoin success was highest on unburnt and slightly burnt specimens. Conjoin success dropped, but remained relatively consistent, in levels between 0-30 cm depth which contains both an increase in the range of thermal modification types and a marked decrease in the frequency of unburnt specimens. Layers with high rates of thermal modification of the faunal specimens (5-30 cm depth) display both fewer conjoins and a marked reduction in the average size of specimens (measured by weight and length, see below).

Given that variations in conjoin success were related to the effects of different taphonomic processes, further checks on stratigraphic integrity using other lines of evidence were also conducted. The scatterplot data and mean size data for bone (Table 10-9), Macrozamia (Table 10-10), and lithics (Table 10-11) indicate that there was not extensive vertical movement of specimens in the site. No patterning or linear relationships were identified in the distribution of specimens, indicating that little size sorting occurred in these components at Wanderer’s Cave. A generally consistent pattern was identified in the size distribution of specimens in levels, and while there are some variations in size of some components and levels, these have been identified as relating to taphonomic processes, particularly of carbonisation of the Macrozamia and calcination of the faunal specimens, rather than trampling. These are discussed further below.

Differential Preservation

At Wanderer’s Cave, there was limited evidence of specific post depositional and diagenetic processes. No specimens displayed root etching, indicating that bones were not in
association with a plant supporting sedimentary environment (Grayson 1984; Haglund and Sorg 2002; Lyman 1994:375-6). Although modification from cattle, insects and microbes were considered, no positive identifications were made. A total of four faunal specimens displayed manganese staining, indicating few specimens had undergone diagenetic changes. There was also limited evidence of weathering on lithic artefacts \( (N = 9) \), and probably indicates a limited amount of raw material recycling. Small scale roofall events occurred in the basal strata (prior to 5021 Cal BP), and small pieces of roofall were documented at 20-25 cm depth (3638 Cal BP), 30-35 cm depth (between 4830 and 5021 Cal BP) and 40-45 cm depth (prior to 5021 Cal BP) and the surface of the deposit (Beaton unpublished fieldnotes, 1977, 1991), which possibly caused local, in-situ fracture of deposited and buried components. Variations in the density of components in levels at Wanderer’s Cave were not related to the burial process of compaction (decreased porosity) with increasing depth (Lyman 1994:424; Retallack 1990:135) as larger specimens are present in the lower levels of the deposit (Table 10-9).

However, several other taphonomic processes controlled specimen preservation, identifiability and stratigraphic integrity during and after the formation of the deposit at Wanderer’s Cave. Major taphonomic processes affecting faunal preservation were identified as 1) weathering, 2) sediment pH, 3) thermal modification, particularly calcination, and 4) canid deletion and modification of elements. All these factors had equal impacts on preservation and identifiability, and are discussed further below. As was found in Rainbow and Cathedral Caves, identification of faunal elements was found to relate to specimen size, and specimen size was largely controlled by both calcination and weathering stage.

**Weathering**

In contrast to Rainbow Cave, the majority of the specimens at Wanderer’s Cave displayed minimal evidence for weathering related modification. A total of 412 faunal specimens (21.76%) formed the analysed sub-sample, selected to be comparable with Behrensmeyer’s (1978) experimental set (refer Chapter 7) (Table 10-12). The entire range of weathering stages was represented in the assemblage, and in all except the surface level, sample sizes were adequate. For the site as a whole, the majority of specimens in this sample \( (N = 295, 71.6\%) \) remained at weathering stage 0; 37 (9%) of specimens had weathered to Stage 1; 19 specimens had weathered to Stage 2 (4.6%); 37 specimens had weathered to Stage 3 (9%), and 13 and 11 specimens had weathered to Stage 4 and 5 respectively (3.2 and 3.7% respectively) (Figure 10-7, Table 10-13, see also Figure 10-8, Figure 10-9). As was found at
Rainbow Cave, significant variation in the vertical distribution of weathering stages occurred at Wanderer's Cave (Figure 10-10). Almost all of the specimens weathered beyond weathering stage 0 occur in the lower levels of the site, between 30-50 cm depth.

The specimens in these layers had weathering stages from all 5 weathering categories represented (Figure 10-7, Table 10-13), and high mean maximum weathering stages (MMWS) ranging from 3.0 between 40-45 cm depth (N = 34) and MMWS 2.86 between 45-50 cm depth (N = 19). In comparison, the MMWS between 35-40 cm depth improve to a MMWS of 1.40 (N = 67) and further reduce in the upper 5-25 cm, where the MMWS was 0. The upper level of the surface is limited by the small size of the sub sample (N = 7) and is not discussed further.

Following Behrensmeyer (1978, see also Lyman 1994), the relationships between weathering stage, animal body size and depth were investigated to analyse if the distribution of weathering stages was caused by differential effects of frequency and distribution of animal body sizes in the deposit (refer Chapter 4)(Figure 10-11). The differences in the MMWS do not appear to be related to animal body size (Figure 10-12, Figure 10-13, Figure 10-14). When the distribution of animal body sizes between levels of the site was analysed, results indicate that all body sizes are present in all levels of the site, and are distributed generally consistently throughout the levels. When the distribution of animal body sizes and weathering stages is considered, results indicate that almost all of the weathered specimens occur in the lower 30-50 cm of the site and occur on all animal body sizes. The marked differences are also not related to sedimentation rates as the trend indicates high MMWS in the layers of the site which took the shortest time to form (19 y/cm), which is the inverse of what would be expected if sediment rates caused differences in MMWS. The levels between 5-30 cm took the longest time to form (125-283 y/cm) and have the lowest weathering rates.

Weathering in the lower levels of the deposit is suggestive of in situ weathering related to sediment acidity. This was confirmed by analysing the relationship between weathering stages and pH in the lower levels of the site. The results indicate that although specimens representing each animal body size are present in all layers of the site, only those in the lower 30-50 cm of the site have been substantially modified by in situ weathering (Figure 10-15). Sample sizes were adequate in all levels except the surface level. As specimens from each animal body size have been differentially affected between the two portions of the deposit, this suggests the operation of different taphonomic processes between 30-50 cm and 0-30 cm depth in the site which has led to the differential preservation of faunal remains.
This evidence suggests that the high level of weathering in the lower levels of Wanderer’s Cave is related to in situ weathering caused by acidity. Further tests were conducted to investigate differential survivorship of burnt and unburnt faunal specimens and pH in the lower levels of the site. Sediment analysis also indicates the faunal specimens were incorporated into sediments, which were formed under environmental regimes promoting acidic sediments (Webb 1992).

**pH**

Several analyses were used to test the potential differential survivorship of burnt and unburnt faunal specimens and pH (following Knight 1985) by 1) counts, 2) mean specimen completeness, and 3) mean weight of burnt and unburnt specimens. Tests of the differential preservation of plant remains and carbonisation level were also conducted.

At Wanderer’s Cave, a clear pattern was identified in the acidic lower levels of the site, specifically the differential preservation of burnt specimens in comparison to unburnt specimens (Figure 10-16, Figure 10-20). The three lower levels of the site have pH 4.5; and have less burnt bone in each level than unburnt bone. This is consistent with the findings of Knight (1985) suggesting differential preservation of unburnt bone in comparison to burnt bone (see also Lyman 1994).

The effects of pH on bone survivorship burnt and unburnt specimens was further tested by analysing variations in specimen size including the mean completeness (Figure 10-17) and mean weight of burnt specimens (Figure 10-18). When mean completeness and weight is considered, variable results were obtained in the lower three levels of the site. Weight shows no clear pattern except for larger pieces of bone in lower levels. Based on this data, there is less bone in more acidic levels which may be related to differential preservation due to the effects of pH; however no correlation was identified with bone loss or completeness because the specimens in high pH levels are larger and more complete.

Given Knight’s experimental results (1985), the potential differential preservation of burnt and unburnt Macrozamia specimens and pH was investigated. When analysed by counts, there is a marked difference in the number of Macrozamia specimens in the two lower acidic levels of the site (30-40 cm depth) in comparison to the upper levels (Figure 10-31). The pattern of Macrozamia survivorship may indicate that uncarbonised specimens, and those at high thermal modification stages (400 °C), are differentially removed from the site in levels
of high pH, while specimens burnt at 200°C are present in acidic sedimentary levels, albeit at lower numbers than when compared to the survivorship in levels above in sediments of alkaline pH (Figure 10-19).

The Faunal Assemblage at Wanderer's Cave

At Wanderer's Cave the faunal sample comprised a total of 1893 specimens weighing 738.08 g, which was a 100% sample of the faunal component. The faunal assemblage was distributed normally with depth when analysed by specimen count, sum of specimen completeness and sum of specimen weights (Figure 10-21, Figure 10-22, Figure 10-23), although tests of vertical movement (discussed previously) suggest this is not a product of trampling of the deposit.

A total of 18 species were identified from Wanderer's Cave, and in general the species represented were similar to those at the other sites due to the similarity of environmental characteristics (Table 10-14, Table 10-15). Petrogales were the dominant species in the site when analysed by both MNI and NISP, with smaller contributions made by Macropods and possums (*T. vulpecula*). Reflecting this, animals of medium body sizes dominated the deposit (49.4%), followed by small animals (16.1%, *N* = 305), and larger sized animals (11.2%, *N* = 212) (Table 10-16). Equal proportions of juvenile animals (8.6%) and adult animals (8.6%) are represented at the site (Table 10-17).

Human Actors on the Faunal Assemblage

Although humans are clearly indicated in site occupation events, the question of who was responsible for the deposition of faunal remains is a significant issue that requires several types of analyses to disentangle. The most direct line of evidence for human interaction in the faunas include 1) analysis of butchery, and 2) thermal modification evidence on species and elements. The latter data is important to determine the timing of burn events.

Faunal Butchery

The most direct evidence for human association and modification on prey carcasses is the identification of taphonomic traces of butchery (Lyman 1994). However, there was very sparse evidence for human modification of faunal elements in Wanderer's Cave, with 16 specimens (0.8%) of the total faunal sample displaying direct evidence of cutmarks, loading
points or force application (including ribs, hackle marks or bone flakes: refer Chapter 4). The low frequency of positive evidence is consistent with Solomon (1985) who found little evidence of human processing of wallaby carcasses in experimental trials, and is also consistent with studies in other parts of the world where relatively low frequency of butchery evidence is identified in archaeofaunas (see Bar-Oz and Dayan 2002, 2003).

The majority of butchery evidence is located in the upper 25 cm of the site. The distribution correlates with the levels showing anthropogenic thermal alteration, and evidence for human force application on lithic and Macrozamia specimens (discussed further below). Different types of butchery traces were identified in these layers, including cutmark evidence associated exclusively with Petrogale sp., and evidence of force percussion associated with femurs and larger long bones of larger Macropod sp., possibly related to marrow extraction. Butchery data is consistent with ethnographic, anthropological and experimental evidence describing marrow extraction (Solomon 1985; Solomon and David 1990). PFA’s are repeatedly located on femurs, which have the highest marrow content (O’Connell and Marshall 1989) and occur on the same element on the same species with anatomical purposiveness (location to extract marrow), and also located on the metatarsal (see O’Connell and Marshall 1989). Loading points are also associated with other supporting lines of evidence of human application of force including hackle marks and crushing. The marks are not associated with trace fossils made by canids. The evidence supports the inference of human involvement in the creation of parts of the faunal assemblage, particularly the Petrogale and Macropod component.

Faunal Thermal Modification

Several taphonomic methods need to be applied and variables considered when analysing the meaning of burnt bone. The thermal modification data at Wanderer’s Cave suggest the majority of bone was burnt when on the surface or were already buried within the sediment when fires were lit at subsequent site reoccupation events. What is also clear is that fresh bone was being regularly deposited into the site by both humans and canids (discussed below). On the whole, the thermal modification record at Wanderer’s Cave is consistent with archaeological and forensic experimental analogues, and suggests that the majority of faunal specimens have been unintentionally modified as a result of the both the consistent location of fires, and taphonomic modification of heat from fires, rather than by intentional “cooking” activities. The evidence for this position is outlined below.
Distribution of Burn Extent

At Wanderer’s Cave, 58% (N = 1098) of the faunal specimens displayed evidence of thermal alteration (Table 10-24). There is evidence for thermally modified specimens throughout the sequence of Wanderer’s Cave, with the majority of specimens distributed in a normal curve between 0-40 cm depth. The majority of burning modification occurred between 5-30 cm depth where over 60% of the specimens exhibited burning modification. As discussed in Chapter 4, specimens can become thermally modified either intentionally or unintentionally, or at discard or in sediments (Grayson 1991; James 1997; Lyman 1994; Stiner et al. 1995), and it becomes essential to identify the timing of thermal modification relative to deposition and burial.

The extent of thermal modification on faunal specimens becomes clear when evidence for burning is analysed 1) over fractures, and 2) in bone interiors (Table 10-18, Table 10-19, Table 10-20). The results also support the inference that the majority of the thermal modification occurred after meat was removed, and after the specimen was discarded, as 93.1% of specimens had burning over the fracture surface and 94.9% displayed burning in their interiors. Only relatively small numbers of specimens did not have a burnt fracture or interior (N = 76, 6.9%; N = 61, 5.6% respectively). This suggests that that bone was consistently being discarded and unintentionally burnt, and that the majority of fractures in thermally modified specimens may have been caused by physical changes induced by fire.

The proportion of carbonised to calcined specimens in the levels of Wanderer’s Cave (Table 10-21) were compared to the results obtained in Stiner et al.’s experimental set (1995). Based on this comparison, three different thermal modification patterns were identified with depth between: 0-10 cm, 15-20 cm and 35-40 cm. Change in fires and the effects of thermal modification of specimens are detectable over the deposit at Wanderer’s Cave. This suggests variations in fire history and effects in the site between levels.

The very low frequency of thermally modified specimens between 35-50 cm depth may be the result of preservation issues related to sediment pH. The lower levels are marked by a low representation of unburnt and burnt bone in sediments with a pH of 5.0, in comparison to levels with a pH of 8.0.

The proportion of the different classes of thermal modification between 10-35 cm is very consistent at Wanderer’s Cave (Figure 10-25 11, see also Figure 10-26, Figure 10-27), and very similar to the pattern found experimentally. Approximately equal proportions of
calcined to carbonised specimens were identified in Stiner et al.'s (1995) experiments (43.68% calcined to 53.9% carbonised) and at Wanderer's Cave (29.69% calcined, and 28.31% carbonised). As the experimental tests use fresh bone, it may be possible to infer that the majority of the specimens that underwent thermal modification at Wanderer's Cave were fresh, having some organic content left at the time of heat application. The similarity in the datasets suggests the thermal modification of fresh animal bones at the site, and that fires were consistently placed near the middle of the shelter floor area, were relatively consistent in duration, extent and temperature, but may have been relatively infrequent.

Three levels of the site displayed a marked deviation in the calcined to carbonised ratio. These levels were 0-5 cm, 5-10 cm and 15-20 cm depth. These levels display a higher frequency of calcined specimens. The possible causes of an increase in the proportion of calcined specimens were further investigated using 1) sediment rates, and 2) differential loss carbonised to calcined specimens. The variations in sediment rate were not responsible for differences in the ratio of calcined to carbonised specimens as increases in calcination occur in periods of both fast and slow rates of sediment formation. The differential loss of incompletely carbonised specimens to calcined specimens is unlikely, as experiments have indicated that specimens with organic content resist fragmentation as a result of thermal modification. Thus the variations in the extent of calcination in the upper levels of the site may reflect real changes in the 1) frequency, 2) intensity, or 3) duration of fires. Alternatively, there may have been an increase in the quantity of bone on the surface of the deposit to be calcined as a result of hearth placement on top of fresh bones, or a change in disposal patterns by throwing bones back into the fire (Gilchrist and Mytum 1986).

Given that any original evidence for "cooking" appears to have been overprinted by further thermal modification events, other evidence was considered to identify cooking. Thermal modification evidence consistent with pit roasting of large Macropods (as indicated by ethnographic evidence and in experimental cooking trials, see Solomon 1985) were analysed. This data suggests some representation of the activities of cooking variations may be identified by investigating 1) animal size, 2) animal age, 3) among the eight most commonly occurring species, and 4) among the 13 most commonly occurring elements. Sample sizes were too small to consider burning modification by element and species.

Overall rates of burning and ratios of calcined to carbonised by age (unknown, young and adult) (Table 10-22), and body size (large, medium, small and unknown) (Table 10-23) at the site indicates that all age groups and body sizes had an even chance to be calcined on the surface of the deposit or be carbonised in sediments. The only category which does not
follow this trend was animals of unknown age and unknown body size (Gilchrist and Mytum 1986; Herrmann and Bennett 1999; McKinley 1994). The calcined to carbonised ratio for the eight most abundant species of the site (Table 10-24) indicates that all species had equal chance of becoming modified while in sediments or on the surface of the deposit. Analysis of elements from these species indicate a consistent incidental of burning on elements, suggesting that the majority of the specimens were burnt while on top of sediment or buried within them (Table 10-25).

Other forms of thermal modification evidence were also analysed to investigate if the temperatures indicated by colour change on faunal specimens were consistent with temperatures attained in sediments as identified in experimental research (refer Chapter 4). The relative age of the faunal specimen at the time of thermal modification was also investigated using morphological changes to the bone surface. Analyses included: 1) temperatures attained by buried specimens as indicated by colour, 2) changes to morphological characteristics and the surficial appearance of specimens due to thermal modification at specific temperatures, and 3) morphological changes to specimens associated with the age of the bone at the time of thermal modification.

Both the colour range (Table 10-26) and morphology of specimens in Wanderer’s Cave is consistent with the thermal modification of specimens within and on top of sediments as indicated by experimental research (Bennett 1999:4; de Gruchy and Rodgers 2002; Gilchrist and Mytum 1986). Analysis of colours on faunal specimens at Wanderer’s Cave indicates that temperatures of sediment between 1-5 cm depth reached between 300 °C and 500 °C, and the temperatures of specimens on the surface of the deposit reached between 600 °C and 700 °C or more. Experimental research, mainly in forensic sciences, has also indicated that changes to the morphology and surface appearance of faunal specimens also occur in these temperature ranges (Table 10-27). Analysis of the surface changes to bone also indicates that sediments between 1-5 cm depth, and the faunal specimens within them, reached between 350 °C and 500 °C, while faunal specimens on the firebed also reached 600 °C and 700 °C.

Overall, there is little direct evidence for human butchery and intentional thermal processing of the vertebrate remains at Wanderer’s Cave. Extensive taphonomic overprinting of original human signatures has occurred as a result of open fires at the site. Multiple lines of taphonomic evidence suggested the majority of faunal specimens were unintentionally burnt both within and on top of sediments. These included 1) the vertical distribution of thermally modified specimens, 2) the consistent proportions of calcined to carbonised specimens in
most layers of the site, 3) consistency of calcined to carbonised ratios of animal age, species
and element, and 4) colour and surficial morphological changes. The pattern at Wanderer’s
Cave is consistent with a number of experiments conducted in both archaeological and
forensic sciences.

The similarity in the results from Wanderer’s Cave in comparison to those from several
experimental sets, allows inferences concerning the use of fire at the site through time. Fires
may have been placed relatively consistently near the middle of the site, where the
excavation unit was placed. The majority of specimens in the 0-30 cm in the site were
modified while it contained organic matter (Gilchrist and Mytum 1986). However this may
not indicate that humans repeated occupation every few years to continually burn bones still
containing organic matter (weathering stage 2: Reed 2001; see also Bennett 1999) as
specimens may have been brought in by dogs, rather than by humans alone. The
temperatures near the surface of the site reached 700 °C or more.

Canid Actors on the Faunal Assemblage

Canids have been important agents of accumulation, modification and deposition of faunal
items in Wanderer’s Cave (Table 10-28 Table 10-29, Figure 10-28, Figure 10-29, Figure 10-
30). Approximately 42.4% of the entire faunal sample displayed evidence of gnawing,
digestive modification or both. The taphonomic effects were almost equally divided between
digestion and gnawing, with 29.5% (\(N=558\)) displaying digestive modification and 21% of
specimens displaying evidence of gnawing modification only (\(N=414\)), while 8.9% (\(N=
168\)) displayed evidence of both gnawing and digestion.

Dogs have been a constant source of faunal modification and deposition throughout the
formation of the assemblage, with both kinds of modification evidence present in all levels
of the site (Table 10-29). However, modification types were unevenly distributed through
the excavated levels; two different distributions of gnawing and digestion occur at
Wanderer’s Cave, where gnawing dominates between 15-40 cm depth, and digestion
dominates between 5-15 cm depth. Sample size is low between 50-40 cm depth (\(N=3\)) and
0-5 cm depth (\(N=12\)) which precludes a detailed analysis. Evidence of canid gnawing
dominate levels between 15-40 cm, where the frequency of specimens displaying evidence
of gnawing modification ranges from 58-38%, while digestion in the same levels ranges
between 16-30%. Digestion becomes the dominant form of modification effect between 5-15
cm depth, ranging between 17-11%, and gnawing falls to 5-10%. Almost equal proportions
of gnawing and digestion occur between 0-5 cm depth which could be an effect related to small sample size (58% gnawing and 50% digestion N = 12). The proportional frequencies of types of canid modification are relatively constant between 5-30 cm depth, with the exception of a drop between 10-15 cm depth, with peaks caused by low sample sizes in the other levels.

As indicated in Chapter 4, even though clear modification effects are evident on faunal specimens, there are considerable challenges in identifying the primacy of humans and dogs in faunal assemblages. There are several ways in which dogs can both modify and deposit specimens into the site 1) from dogs bringing in their own meals, 2) dogs modifying humanly caught animals, or 3) dogs depositing either wild caught or human caught elements into the site as modified elements or scats. Several analyses were performed to interpret and differentiate faunal modification patterns at Wanderer's Cave.

As discussed in Chapter 4, the major biomass supporting dingoes in several regions of Australia are small and medium sized animals, which can form up to 80% of the diet, and 20% of the diet comprised of larger animals (Corbett 2001). The frequency of canid modifications by animal body size was analysed for the site (Table 10-30). The results are consistent with ecological data, as at Wanderer’s Cave, animals of small and medium body sizes had the highest evidence of canid modification evidence at 29.8% (N = 580) with less evidence for canid modifications of animals of larger body sizes (4.6%, N = 89), and those of unknown body size (7.1%, N = 134). This data suggests that dingoes have been responsible for the modification and deposition of a significant portion of these animal size categories in the site (further details see Chapter 4). This was a consistent pattern over the analysed over the three CQH sites.

Given this result, further investigations focussed on Petrogales and Macropods to investigate primacy of human and canid involvement with these species at Wanderer’s. Several analyses were performed, including 1) digestive and gnawing evidence on Petrogales and Macropods, 2) the age structure of the Petrogales and Macropods in Wanderer’s Cave, 3) differential representation of body regions, 4) differential representation of elements, and 5) diagnostic regions on elements. The methods used to investigate these patterns are presented in Chapter 4.

Analysis of the distribution of canid modification across all species indicated that sample sizes were low for most species, with the exception of Macropods and Petrogales (Table 10-35). The results of the analysis of digestive and gnawing modification on Petrogales and
Macropods at Wanderer’s Cave (Table 10-31) indicate that Petrogales show higher rates of all canid modification types (50.9%, \( N = 258 \)) in comparison to Macropods (42.9%, \( N = 82 \)). When analysed by canid modification type, the rate of digestive modification was higher for Petrogales (22.1%, \( N = 112 \)) than Macropods (7.4%, \( N = 14 \)). In contrast, the rate of gnawing modification was higher on Macropods (24.6%, \( N = 47 \)) than Petrogales (15%, \( N = 76 \)).

Very similar frequencies of modification types and species selection were also identified at Rainbow Cave.

In order to distinguish between human and dingo prey selection, the age structure of all of the Petrogales and Macropods in Wanderer’s Cave were analysed (Table 10-32). The data indicate an almost even distribution of both adults and non-adult Petrogales and Macropods in the site. At Wanderer’s Cave, only a moderate difference occurred in the proportions of adult Petrogale to Macropod specimens (11.0% adult Petrogales \( N = 56 \)) in comparison to 18.3% adult Macropods \( N = 35 \). When the age structure of canid modified Macropods and Petrogales are analysed, the inverse of this pattern is evident, where the frequency of non-adult Petrogales is slightly higher at 15.0% \( N = 77 \) in comparison to non-adult Macropods at 12.6% \( N = 24 \).

The evidence for digestive and gnawing modification on Petrogale and Macropod was considered by age group. Postcranial data were used due to the lack of cranial data (Table 10-33 and Table 10-34). A very similar pattern was evident in canid digestive modifications for non adult Petrogales, at 36.4%, and adult Petrogales at 33.9%. Gnawing evidence was relatively even between adult Petrogales at 9.2% \( N = 7 \) and juveniles (7.9%, \( N = 6 \)) although sample sizes are small.

The differential preservation of body regions was analysed for Petrogales and Macropods at Wanderer’s Cave (Table 10-36). Unfortunately the low sample sizes did not permit analysis of canid modification type by body region. The data from Wanderer’s suggests decreased representation of forearms, back, chest and feet relative to the hindlimbs (Hudson 1993). These patterns are inconsistent with the natural disarticulation of Macropods ascertained by Reed (2001), but are consistent with modification patterns by dogs in other studies (Hudson 1993; Solomon and David 1990).

To further investigate whether patterns of faunal modification were consistent with canid reduction, patterns of digestion and gnawing on elements of Petrogales were considered, although sample sizes were small. The elements which show digestion and gnawing
modification are consistent with available ecological data concerning the preferences of the dingo (David 1984; Solomon 1985). The elements most frequently displaying evidence of digestive modification (Table 10-37) included caudal vertebrae (63.65%, N = 14), and phalanges (66.7%, N = 16), with other elements including the cranium, femur, fibula, humerus, mandible and tibia ranging between 18.5-31.8%. The elements most frequently displaying evidence of gnawing modification was highest on the elements with the highest structural density, the femur (32.9%, N =23), tibia (36.4%, N = 49) and mandible (37.7%, N = 9). For other elements, including the cranium, fibula, and the humerus, gnawing modification ranged between 15.6-21.1%.

Interestingly, those elements that have lower rates of gnawing modification have high rates of digestive modification. These included caudal vertebrae and phalanges (4.5% and 4.2% digestive modification respectively). More limited data was available for gnawing and digestion by element for Macropods, and as such analysis focussed on the fibula, rib and tibia across the site as a whole. The data indicates that ribs and fibula show most digestive evidence (17.6%). Gnawing was highest on Macropod tibias (28.6%), consistent with the high structural density of this element. As was identified at the other two sites, end to shaft ratios indicate the absence of both proximal and distal epiphyses of both tibias and femurs of both Petrogales and Macropods and support the inference of canid modification of faunal elements at the site (Table 10-38).

Overall, at Wanderer’s Cave, several patterns of canid occupation of the site, with and without humans, have been identified. Evidence suggests that canids have targeted animals of small body size, and adults and juveniles of Petrogales and large Macropods. Studies on wild dog and dingo aged based predation patterns suggest this pattern is most consistent with prey selection of juvenile Petrogales by individual dingoes around the cave site. The overall age distribution for the site indicates a non-normal distribution of age classes for Macropods and Petrogales, a pattern which was also identified at Rainbow Cave. This is consistent with ecological data, which suggests hunting of non-adult Petrogales by dingoes, either by individual dogs associated with human camps, or dogs which have become unassociated with camps. It is possible that the site was used as a den during portions of site formation.

**Rodent Actors on the Faunal Assemblage**

Rodents have not been a significant faunal accumulation or modification factor at Wanderer’s Cave (Table 10-39). Only 19 instances (1%) of rodent modified faunal
specimens were identified at Wanderer’s Cave, identified from levels associated with human activity, between 5-40 cm depth. The frequency of gnawed items in each level was low, ranging between 1-3 specimens (0.4-1.7%), with the greatest activity identified in 20-25 cm depth where nine specimens (2.0%) were identified. The rodent gnawed sample from the site show variable weights, lengths, widths and thickness, indicating the selection of the properties of the specimens may have been random. The average estimation of element completeness for rodent gnawed bones was 30.26%.

Gnawing was concentrated on the midshafts of unweathered (less than weathering stage 0), long and thin bones. The mean area of gnawing was 50% or less of the surface area, and often 5% of the surface area of the bone. Almost an equal proportion of gnawing occurred on both burnt and unburnt specimens. The elements came from a narrow range of species, including 10 specimens from Petrogale sp., four unidentified species and four from unidentifiable Macropod specimens and one T. vulpecula. Skeletal elements of rodents were identified from 5-10 cm depth, supporting the idea that rodents were living and dying in the site, as there was no evidence that these elements were deposited by owls (Lyman 1994). The low frequency of rodent gnawing on faunal elements suggests that they were infrequent visitors to the site. The slightly higher frequency of rodent gnawing at Wanderer’s Cave in comparison to Rainbow Cave is probably due to both the proximity of Macrozamia plants to the site (providing a temporarily restricted resource to exploit) and the protected nature of the shelter in which to “security eat”. As most of the rodent gnawing evidence is associated with Macrozamia, this is discussed further below.

The Macrozamia Assemblage

A 100% sample of Macrozamia specimens at Wanderer’s Cave formed the analysed sample of 1514 specimens, the highest NISP of all the three sites (Table 10-40). Specimens were distributed unevenly between 0-40 cm depth (5021 Cal BP), with a peak between 5-10 cm depth at 543 specimens, while in all other levels counts ranged between 151-250 specimens (Figure 10-31). Specimens comprised of part of the seed shell with part of a diagnostic end present (shell), or specimens without a diagnostic end (body) (Table 10-41, Figure 10-32). Other specimens associated with complete stroboli were also identified, and suggest that for some levels of the site seeds attached to stroboli were being brought to the site, including two sporophyll pieces from 15-20 cm depth. Other materials associated with seeds themselves included three fragments of sarcotesta between 30-35 cm depth, four desiccated
kernels between 15-20 cm depth, and a complete unopened shell with a desiccated kernel between 20-25 cm depth.

Non-Human Actors on the Macrozamia Assemblage

Although several animals were identified as collectors, transporters and predators on seeds in Macrozamia communities, only rodents were identified as taphonomic agents at Wanderer’s Cave. Of the three sites, Wanderer’s Cave had the second highest frequency of rodent modification (Table 10-40), and rodents are likely to have been responsible for transport and deposition of seeds to the site. A total of 205 specimens (13.5%) of the Macrozamia assemblage at Wanderer’s Cave had evidence of rodent gnawing the outer shell, emplaced as a result of eating of the outer fleshy sarcotesta (Table 10-42). Relatively few seeds had evidence of rodents opening the shell to extract the kernel (N = 15, 1%). Both rodent modification types were identified from each level of the site. The rodent breach of the shell occurred in small frequencies in each layer, ranging from 5.66-1.32% (Table 10-43). In contrast, consistently high rates of gnawing of the sarcotesta occurred between 35-40 cm depth (20%) and the upper 20 cm of the site (15-27%) (Figure 10-33). Lower frequencies of specimens with gnawed flesh occurred in the middle of the deposit between 20-35 cm depth (7-10%). The reduction in taphonomic traces occurs in levels with high rates of thermal modification of specimens to 200 °C and 400 °C, suggesting reduced identifiability of these taphonomic traces with increased thermal modification of the surface of the specimen. Overall, rodent gnawing occurred on both weathered and fresh specimens at the site (Table 10-50).

Human Agents of Macrozamia Modification

Several features of the Macrozamia assemblage suggest that although severely altered by carbonisation, the majority of seeds may have been opened as a result of human force. All fracture patterns analysed for Wanderer’s Cave were consistent with those generated in the experimental set. Direct evidence of human processing of the specimens included 1) fracture patterns produced as a result of the human application of force, and 2) thermal alteration of specimens consistent with anthropogenic temperatures consistent with results obtained from experimentally processed Macrozamia.
Fracture Techniques

At Wanderer’s Cave, it was possible to identify the agent opening Macrozamia seeds for 27.8% of the specimens ($N = 422$). The majority of these displayed characteristics consistent with human force ($N = 414$), while comparatively few specimens were opened by rodents ($N = 15$), while no specimens appear to have been opened by insects (Table 10-44). While 1092 specimens did not display PFA attributes (ringcracks, hair fractures), this is consistent with taphonomic modification identified from the experimental trial (Chapter 7), which indicated a reduction in the evidence of PFA occurs on specimens that have been thermally modified. Evidence for PFA, including ringcracks and body fractures, fall from 44% and 36% respectively for specimens processed at 200 °C to 18% and 12% respectively for specimens burnt at 400 °C.

At Wanderer’s Cave, the sample sizes were adequate to investigate fracture evidence in all levels with the exception of 35-40 cm depth ($N = 5$). Specimen fragment types (portion shape) (Table 10-45) were dominated by body portions (61.2%) which were created at PFA or anvil rebound fractures ($N = 927$), or transverse and longitudinally fractured specimens 28.8% ($N = 436$); 6.7% transversely fractured specimens ($N = 101$) and 3.3% longitudinally fractured specimens ($N = 50$). Shape data shows some differences between the sites, with specimens in Wanderer’s Cave having similar rates of longitudinal fractures in comparison to the other two sites, but has more body portions, and less transversely fractured specimens and less transverse and longitudinally struck specimens. A comparison of the latter two trends to the results obtained in the experimental set indicate that carbonisation extent, and increase in force PFA at the site may be the variables causing these differences. The mean completeness of the diagnostic ends of the specimens at Wanderer’s Cave was also much smaller than the other sites (Table 10-46, Table 10-47, Table 10-49), and the experimental sets. This may be a result of a combination of more force being used to process the archaeological specimens and the higher carbonisation extents reached at the site.

The analysis of the completeness of the ends of ends and ringcrack data suggests that humans used side striking to open the seeds in the site. At Wanderer’s Cave, higher frequencies of complete ends are indicated rather than both ends (Table 10-46, Table 10-22, Table 10-48). This occurred in all burn extent categories indicating consistent reduction patterns. A second line of evidence was used to analyse opening techniques. The location of ringcracks on the specimen also suggest side striking with higher rates of ringcracks on sides than for ends in all temperature groups (Table 10-46).
Thermal Processing of Macrozamia

There are variations in the carbonisation extents through time at the cave (Figure 10-34), although all specimens show thermal alteration consistent with temperatures used by humans to process specimens for consumption. Approximately 26.8% of the Macrozamia in the site do not display any evidence of thermal modification (N = 406), while 64.9% displayed modification of thermal modification to 200 °C (N = 983), and 8.3% displayed carbonisation extents consistent with modification to 400 °C (N = 125). Macrozamia specimens appear to have been consistently burnt to temperatures (200-400 °C) as a result of intentional roasting by humans, with some specimens being carbonised, either as accidental overcooking, or from secondary exposure to fire possibly after roasting.

What is striking about the sample from Wanderer’s Cave is that average specimen size is lower than the other sites, and in comparison to the experimental set (Table 10-49). This pattern may be a result of the extent of thermal modification. The threshold effect at 400 °C that was identified in the experimental set was apparent at Wanderer’s Cave where specimen completeness reduced from 19% at 0 °C, 15% at 200 °C and 9% at 400 °C.

Age of the Seed at Processing Time

At Wanderer’s Cave, 11.6% of specimens contained evidence of sarcotesta on the shells (Table 10-40). These specimens were unevenly distributed with depth (Figure 10-35), 40% of specimens between 15-20 cm depth had sarcotesta evidence, in comparison to the generally low rates between 0-35 cm depth, which ranged between 5-15%. High rates of weathered specimens occurred in the lower deposit at 35-40 cm depth (20%), 5-10 cm depth (30%), and also in the surface level at 0-5 cm depth (80%). In contrast the rate of weathering on specimens was very low between 15 and 35 cm (Figure 10-36). The sarcotesta data and the weathering data indicate that people were collecting both fresh seeds off plants and weathered seeds from prior seed production events. Changes through time in seed selection are discussed further in Chapter 11.

It is notable that the density of Macrozamia at the site (1514 specimens per m³) is much higher than the value estimated by Beaton (400 specimens per m³) (1977, 1991). An estimate of MNI based on the sum of specimen completeness for all specimens indicates a MNI of 238.57 nuts. However the MNI estimates drop considerably when the sum of the estimations of the completeness of diagnostic ends are used, where 134.29 nuts are indicated based on
micropylar end completeness, and 131.16 nuts are indicated when based on attachment end completeness. The MNI estimates indicate the equivalent of one stroboli was deposited over the last 4,000 years at the site, and even when a conservative estimate of one nut to account for all the NISPs at the site, 1514 nuts equates to 5.04 stroboli (where one stroboli contains 300 nuts) over the last 4,000 years.

Combinations of archaeological, taphonomic and ecological data can be used to make interpretations concerning seed and cone availability at the time of the human use of the site, and Macrozamia in the area around the site. This was done by analysing 1) evidence for collection off cones, 2) weathering data, and 3) rodent gnawing patterns. Chapter 11 discusses the ecological data on which the following interpretations are made.

A shift is evident in Wanderer’s Cave concerning the collection of seeds in the site that may be related to environmental conditions and seed production. Although the sample size is small, the seeds between 35-40 cm depth (N = 5) were weathered and also had rodent toothmarks. There is a marked change between 15-35 cm depth where collection of complete stroboli from plants is suggested by the presence of pieces of the inner stroboli. The presence of unburnt fragments of sarcotesta may have fallen from stroboli prior to thermal processing of the cone. During this time, rodent toothmark evidence was of very low frequency, which may be related to high thermal modification removing this evidence at this time and or the collection of complete, fresh stroboli. The seeds in the upper 10 cm of the site display high levels of rodent toothmarking, and high weathering rates of seeds. High rates of rodent gnawing in the upper 10 cm of the deposit may indicate collection of fresh seeds from a masting population, as ecological data suggests rodent toothmarking is higher in such events (further discussed in Chapter 11). The high weathering rates on seeds would also suggest people were collecting available fresh seed from decaying cones, and collecting seeds from prior masting events which have been weathered beneath plants (refer Chapter 11).

Weathering data suggests the collection of seeds weathered beneath the trees, rather than the rodent collection of fresh seeds which have then weathered in the site, as the weathering stage is consistent with specimens weathered in natural environments under parent plants. There are three possible sources of weathered seeds: by storing fresh seeds, collection of aged seeds from the base of a plant after a recent coning event, or collection of aged seeds from the base of the plant (< 12 months prior). The collection strategy suggested here is also
supported by fracture data, which indicates that Macrozamia in the upper levels were not burnt but weathered, in contrast to lower levels, which indicate the burning of fresh seeds.

In summary, the presence of both fresh and aged seeds in the site through time is a pattern which is consistent with modern ecological data for seed availability in Macrozamia populations, and suggests people are using fresh cones collected off plants, and seeds from prior coning events. A change seems to be indicated in collection strategy from fresh, complete cones to individual weathered seeds. This may indicate either different seed production from the mid to late Holocene, or different collection strategies, or increase in occupants requiring the collection of more nuts. This pattern suggests that people are using what is available in the region at the time of visitation, and that the occupation of the site is not contingent on seed production.

**Lithics**

*Overview of the Assemblage*

The lithic assemblage at Wanderer’s Cave comprised of 261 artefacts (Table 10-51). Of these 187 were classified as flakes, flake fragments or retouched flakes. The assemblage was dominated by flakes and flake fragments. The assemblage contained two cores but no hammerstones (Table 10-52).

*Raw Materials*

Raw material type was identified for each stone artefact then classified into four broad categories based on general siliceousness in order to analyse the impact of raw material properties on rates of taphonomic alteration. As indicated in (Figure 10-37), glassy and fine-grained materials dominate all layers except 0-5 cm, where the sample size is very small (\( N = 5 \)).

*Microdebitage*

Sediment samples were analysed for evidence of microdebitage. A total of 17 microdebitage flakes were identified from -2 and -1 \( \phi \), indicating that humans were knapping at the site. The highest frequencies occurred between 30-35 cm depth and 10-15 cm depth, with five specimens identified from these layers. All other levels had one specimen with the exception
of 5-10 cm depth, which contained two specimens. The distribution of microdebitage does not correlate with frequencies of lithic specimens in these levels, and as microdebitage flakes were identified from levels with relatively slow rates of deposition, it is possible that these small flakes were produced as a result of attrition to the margins of flakes. That knapping occurred in the site is also supported by one conjoin of two quartz flakes which had been knapped using bipolar technique from 25-30 cm depth.

Heating of Stone

Low frequencies of heat modified lithic specimens were identified at the site, with a total of 15 specimens (11 that were flakes, flaked pieces or retouched flakes) (Figure 10-38). Of these, the majority displayed potlidding modification, consistent with direct exposure to fires. One specimen between 10-15 cm depth displayed evidence of thermal alteration, indicated by colour change. These data are consistent with the thermal modification identified in faunal specimens, and suggests incidental heating of lithic specimens either buried in sediments or directly beneath fires.

Stone Trampling

As discussed in Chapter 5, several lines of evidence were used to investigate the potential of taphonomic modification as a result of trampling in the deposit. These included rates of 1) edge damage, and 2) transverse snapping. The analysis was restricted to flakes, flake fragments and retouched flakes to provide a controlled sample for the analysis ($N=187$).

Overall, there is a high rate of edge damage at the site compared with Rainbow Cave and Cathedral Cave (Figure 10-40). A total of 97 specimens (52%) of 187 analysed artefacts showed positive evidence for edge damage. Attrition to the edges of artefacts occurred throughout all levels of the deposit. The mean percent of specimens displaying edge damage varied from 25-74% in levels with at least 20 specimens. No obvious pattern was identified when analysed by level (Figure 10-38).

There are a number of factors that can affect the rate of edge damage 1) raw material type, 2) heating of stone, and 3) edge angle (Mitchell 1988). These variables were examined in relation to complete flakes, flake fragments and retouched flakes to test whether they explain...
the higher rate of edge damage at the site, or contribute in a significant way to variations by level within the site.

Glassy and fine-grained raw materials have a higher overall rate of edge damage at all three sites (Figure 10-39). However, the proportion of the assemblage created on these materials remains relatively constant throughout the history of the site, varying between 65% and 100% by layer. The layer with the highest proportion of coarse-grained materials has the lowest rate of edge damage, so some effect is likely. However, raw material difference cannot explain the overall higher rate of edge damage at the site: the overall breakdown of raw material is very similar to Rainbow Cave and slightly more coarse-grained than Cathedral Cave (Figure 10-41).

Unlike Rainbow Cave, no clear relationship was identified between edge damage and heating (Table 10-53). The rate of edge damage on heated flakes was 54.5% ($N = 11$), compared to 51.7% on unheated artefacts ($N = 176$). Heating might be contributing to the high rate of edge damage between 25-30 cm depth. Overall, Wanderer’s Cave has a mean rate of heating of 5.9% (compared with 3% for Rainbow Cave and 8.2% for Cathedral Cave). This indicates that even if heating did make stone more vulnerable to edge damage, the effect seems to be minimal, and does not account for the differences in the rate of edge damage between the sites.

Shallower edge angles make stone artefacts more vulnerable to edge damage (refer Chapter 5). If the artefacts at Wanderer’s Cave had significantly shallower edge angles this might explain the higher rates of edge damage. At Wanderer’s Cave the mean edge angle was 24.5°, compared with 21.8° at Cathedral Cave and 26.5° at Rainbow Cave, but the rate of edge damage was the highest of the three sites. This is supported by the fact that the average edge angle of the analysed artefacts in Wanderer’s Cave with edge damage was 24.9°, compared with 24.2° for those without edge damage (Table 10-54, Table 10-55).

After controlling for the effects of edge angle, raw material, heating, general shape and size, there was no indication that technological or morphological factors had a significant impact on the rates of transverse snapping or edge damage. Any differences between the sites most likely reflect the intensity of trampling or similar taphonomic processes at the site.

The overall rate of transverse snapping of flakes and flake fragments was 20% ($N = 37$), varying between 13-32% in layers with at least 20 artefacts (Table 10-56). There is no clear
relationship between raw material and rates of transverse snapping (Figure 10-42). Analysis of shape and size attributes suggest that the rate of transverse snapping appears to relate primarily to the thickness of the artefacts, with thinner artefacts more likely to be snapped, and the overall rate of trampling.

As discussed above, no positive evidence was identified in the size sorting in the vertical distribution of lithic specimens indicating vertical movement as caused by trampling (Table 10-57, Figure 10-43). There is no obvious correlation between rates of polish on stone within the site and the stone or bone evidence relating to trampling. At Wanderer’s Cave, 21 specimens (8%) of the lithic assemblage displayed polish. All the polish was not associated with the edge of the artefact, but occurred on the dorsal ridge or prominence (Table 10-58). This suggests that trampling may have caused polish on the flakes. Polished artefacts occur in all levels of the deposit above 40 cm depth, in relatively low numbers, and indicate trampling polish is a consistent taphonomic process in the site. The highest frequency of polished artefacts occurred in the lower strata between 35-40 cm depth with seven specimens (34.6% total polish specimens), and between 15-20 cm depth (15.4% of total polished specimens).

Overall, the rates of edge damage and transverse snapping through time show a similar trend. Both these modification types were not caused by thermal modification and are unrelated temporally to the period of major thermal modification at the site as indicated by faunal data. Given that attrition to specimens can occur after relatively little trampling, the trends may indicate the more frequent, and short periods of occupation of this small site, and the low sedimentation rates between 5-35 cm depth (706-4830 Cal BP).

**New Interpretations of Site Use**

Previous interpretations of the site can be considered in relation to the taphonomic and archaeological analyses identified here. At the end of Beaton’s excavation he made several statements about the occupation of the site, which were related to the environmental position and local resources available to inhabitants. Beaton considered that difficulty of access, distance to water, the relatively small floor area of the cave at 70m², and the small quantities of local faunas (Beaton 1991a: 18-19, 22, 31) were limiting factors on the occupation of the site. However the local availability and the site’s proximity to Macrozamia plants was argued to provide the reason for visitation to the site (Beaton 1991b:19). Beaton also considered preservation issues at the cave: Macrozamia preservation may have been
enhanced by carbonisation. The preservation of fauna in comparison to Rainbow Cave was good, although sediment acidity in the lower levels of the site was potentially a taphonomic factor, and some vertical movement may have occurred in the upper deposit (Beaton 1991:29).

The taphonomic history of the site can be characterised as 1) low visitation prior to 4150 BP, 2) increase in visitation by humans and dogs, and use by dogs alone, between 4150 and 820 BP, and 3) a reduction in evidence for human occupation and a possible return of canid occupation after 820 BP. Taphonomic processes have acted to modify, overprint or delete substantial portions of the deposit in each level. There was minimal evidence of human visitation or occupation between 30-50 cm of the site (4380-5021 Cal BP) based on burning and butchery evidence. However, this may be caused by differential preservation of burnt and unburnt specimens as a result of variations in sediment pH. The high sediment acidity in the lower levels of the site also caused an increased fragmentation of in situ specimens. This portion of the site contains the highest rates of taphonomic modifications, and specimens have been modified by only singular process, including thermal modification, weathering and canid transformations; and several specimens indicated modification by cumulative processes including canid modified specimens which have been subjected to thermal modification and weathering; canid specimens further altered by thermal processes, and weathered specimens which were thermally modified.

An increase in human visitation of the site may have occurred between 0-30 cm depth (706 - 4830 Cal BP), based on a comparatively increased frequency and consistency of thermal modification events, although this is not reflected by a significant increase in trampling modification at this time. During this period however, both dogs and humans are indicated as faunal depositional and modification agents. Thermal data suggests the incidental modification of faunal and lithic components. Both thermal processes and canid modification and deletions have overprinted the original signature of human hunting activities in the site. Analysis of the canid modification evidence from this period indicates dogs were both modifying human caught large Macropods, bringing in, or modifying adult Petrogales, and depositing remains of juvenile Petrogales. These patterns are consistent with camp dogs and or wild dogs using the site as a den. Humans appear to have made use of local Macropod resources, while dogs appear to have made use of all local resources.

Humans also appear to have collected relatively low quantities of available Macrozamia cones and seeds while foraging in the area around the site. A reduction in evidence for
human occupation and a possible period of dog only occupation occurs after 820 BP. During this period there is also evidence for stone artefact manufacture within the site, and increased discard of lithic specimens. Some modification and fragmentation of both faunal and lithic specimens is indicated. This portion of the site contains the second highest rate of taphonomic modifications, and specimens have been modified by only singular process, including thermal modification and canid transformations; and several specimens indicated modification by cumulative processes including canid modified specimens secondarily thermally altered, canid modified specimens that were secondarily weathered, and weathered specimens which then became thermally modified.
Chapter 11: Re-Examining Models of Macrozamia Use in the Central Queensland Highlands

Cycads are notoriously recalcitrant reproducers (Vorster 1995:379).

Prehistoric mundane use of the cycad was almost certain reality, but it has mostly mundane implications, and these do not easily fit the archaeological evidence (Beaton 1977:195).

There is no such thing as the final or ultimate interpretation - only better approximations of past reality (Gould 1980:46)

Introduction

In this chapter, the current model of the human use of *M. moreii* in the Central Queensland Highlands is re-examined in the light of archaeological, ecological and taphonomic data. It is argued that there is more variability in the densities of Macrozamia remains in the CQH sites than was presented by Beaton (1977, 1991a, 1991b); and there is no archaeological evidence of the sustained, managed exploitation of Macrozamia as described by Beaton (1977, 1991a, 1991b).

More recent ecological data is used to identify natural constraints on Macrozamia production in order to argue for opportunistic use of an inherently unpredictable and unreliable resource that is not amenable to human manipulation (intervention within a generation). The notion of sustainable intensive use of this resource is based on an incorrect model of Macrozamia seed production. While large-scale use away from the archaeological sites cannot be ruled out, the available archaeological, ecological and taphonomic data strongly suggest intermittent low-intensity use of both the sites and surrounding Macrozamia plants.

Establishing the Problem

*Beaton’s Model*

As discussed in Chapter 2, Beaton argued that the *M. moreii* in the CQH archaeological sites should be interpreted as the debris of the intensive exploitation of this resource to support large-scale ceremonial feasting events. Beaton estimated that the densities of *M. moreii* in
the sites of the CQH were between 400-600 specimens per m³ (Beaton 1977, 1991a, 1991b). Because the investment in energy to process cycads for consumption was high, he interpreted these densities as evidence of more than a subsistence based or “mundane use” of the plant in the region (Beaton 1977:196, 1982, 1993). He pointed to other ethnographically documented resources, which allowed groups to come together on mass, including the Bunya Pine, *A. bidwillii* (Beaton 1977:198) and the Bogong Moth, *A. infusa* (Beaton 1977:199; Flood 1980).

Data available at the time regarding Macrozamia ecology suggested that to achieve the large densities of Macrozamia seeds in the archaeological sites of the CQH, some kind of human intervention would be required. It was known that seed production in some species could take up to 18 months (according to Brough and Taylor 1940). Seed production by individual plants and larger populations of *M. moreii* was characterised as irregular and non-annual; however some populations would produce stroboli each year in the CQH (Beaton 1977:167). What would later become known as “mast seeding” produced large quantities of seeds in the dry season (July-October) in the CQH (Beaton 1977:140).

Beaton argued that fire had been used to stimulate and synchronise seed production in cycad plants, producing massive crops of seeds, which were able to support large populations at ceremonial events (Beaton 1977, 1983, 1991a, 1991b). At the time of Beaton’s analysis, there was limited data available concerning the temporal regularity of cone production in cycads, in either fire climax habitats, or habitats infrequently experiencing fire. However, the evidence available at the time suggested to Beaton that firing groves could result in synchronising and stimulating increased seed production, producing beneficial effects for hunter-gatherers (Beaton 1977, 1982).

The argument that fire could be used to increase the abundance and productivity of cycads, and other economically important plants through frequent and systematic burning had been previously made by other researchers. At the time, Jones had recently established the argument of “firestick farming” (1969). However, the most influential set of arguments concerning cycad seed production by fire were made by Harris (1974). Harris argued that burning tropical woodlands in Cape York and Arnhem Land increased the productivity of the seasonal staple *C. media*. Harris argued that fire in this habitat favoured fire resistant cycads relative to competing shrub vegetation, with fire also exposing old nuts on the ground surface. He suggested that the recurrent burning of stands would be a practical management activity that in the long run, would increase the overall number of plants and therefore the
productivity of the stand for human consumption (Harris 1974, see also Beaton 1977:169). Only two studies of the effects of fire on seed production in cycad populations were used by Beaton: Harris’s observations (1974) and his own observations of *M. communis* at Moruya (Beaton 1977). Beaton paraphrased Harris’ arguments and further argued that as fire caused “super-abundances” of seeds, hunter-gatherers could plan their future exploitation of abundant seeds produced in cycad groves (Beaton 1977:197).

**Re-Examining Cycad Densities in the CQH**

Beaton claimed that densities of *M. moreii* shells were in the order of 400-500 per m³ in the three sites in the CQH. Beaton stated that at Rainbow Cave, the “excavation screens, filled with about 2 kg of sandy matrix, would sieve out dozens to hundreds of *Macrozamia* shell fragments…the quantity of shell fragments suggest that about 400-500 nuts per m³ would be a conservative estimate” (Beaton 1991a:12). At Wanderer’s Cave, “the dry fine matrix poured straight through the sieves leaving behind a very few stone flakes and a lot of burnt *Macrozamia* seed shells” (Beaton 1991a:24). At Cathedral Cave, Beaton claimed “the abundance of *Macrozamia* seed shells was difficult to estimate due to the fragmentation of the shells themselves. A conservative estimate of their abundance would put their numbers at somewhere between the amounts seen at Rainbow and Wanderer’s Cave: e.g., about 500 per m³” (Beaton 1991b:81). Beaton interpreted these densities as evidence of more than a subsistence based or “mundane use” of the plant in the region.

However, this notion of abundant *Macrozamia* remains is not supported by the reanalysis of the *Macrozamia* from the three archaeological sites. Rather than a consistent density of 400-500 specimens per m³ in each site, a far more variable density occurs between the sites. Also, better estimations of the minimum numbers of individual seeds obtained in this analysis do not suggest the intensive use of *Macrozamia* as argued by Beaton. As discussed in Chapter 6, several methods were applied to check the original density estimates, including NISP, density per m³, MNI based on the sum of estimates of specimen completeness, and MNI based on sums of completeness of each diagnostic end (MNE), where the greatest number was taken as the MNI. An estimate of the numbers of stroboli represented in the site was obtained using the MNI and NISP for seed specimens and compared with the average number of seeds contained in one stroboli for female *M. moreii* plants, the average of which is 300 nuts (Beaton 1977; Jones 1994; Rolf Kyburz, pers. com; pers. obs.).
Estimates of *M. moreii* density are presented in Table 11-1. The average density of specimens per m$^3$ varies between the sites, ranging from 113 specimens per m$^3$ at Rainbow Cave, to 1514 specimens per m$^3$ at Wanderer's Cave. The densities were calculated in two ways at Cathedral Cave: one using densities per m$^3$ which included sediment derived from fluvial deposition, and one which avoided fluvial sediment in volume estimates, using densities in the upper 50 cm of the site where the majority of *M. moreii* remains were located. The densities of Macrozamia specimens in the upper 50 cm is a better approximation of true density at the site and at 354 specimens per m$^3$, approximate the lower density estimates of 400 seeds per m$^3$ as estimated by Beaton.

Estimates of the minimum numbers of seeds at the sites were calculated to test Beaton's argument that Macrozamia densities were consistent with the amount of discard expected at ceremonial events (Beaton 1977, 1983, 1991a, 1991b). The MNI estimates based on estimates of specimen completeness for all specimens for all sites suggest very low numbers of nuts and stroboli in these sites over the last 4,000 years. The highest MNI for each site suggest 503 nuts, or 9.6 stroboli at Cathedral Cave, 240 nuts or five stroboli at Wanderer's Cave, and 23 nuts or 0.37% of one stroboli at Rainbow Cave. MNI estimates based on percent end completeness are considerably less than those obtained using estimates of specimen completeness. Estimates of the total number of nuts contained within the entire areas of each site show that the number of nuts required to be deposited range from 7.89 nuts per year at Rainbow Cave to 80.8 nuts per year at Cathedral Cave (Table 11-2). This not only suggests mundane use rather than ceremonial use, but also suggests that a large co-operative collection effort was not required.

The archaeological data raises the question of how hunter-gatherers used this resource in the past. More recent ecological data shows that Macrozamia productivity is far more complicated than was known in the 1970s, suggesting that there are a number of constraints on seed production. The notion of stimulating and synchronising Macrozamia seed production through regular burning is inherently unlikely, as recent studies indicate that fire not only produces variable results in seed production, but can also result in detrimental changes to population structure that cannot be recovered for several generations, if at all. Also, the implication of Beaton’s argument, that Macrozamia populations can withstand the continual collection of seeds in large quantities, is unsupported by ecological data which suggest that intensive collection strategies cause adverse effects on plant populations.
Ecological Data: Understanding Constraints on Macrozamia Productivity

Population structure and seed production in cycad populations are not stable or easily manipulated. Given this, it is important to explore what effects the variability may have had on the hunter-gatherer use of the plants and activities at the time of occupation of the CQH region. There are at least five main factors influencing the production of female cones and seeds, which affect the quantities available for collection by hunter-gatherer populations: 1) the sex structure of the population, 2) the age structure of the population, 3) variables in frequency of seed production, 4) the environmental context, and 5) frequency and intensity of fire. These variables can lead to significant spatial differences and place limitations on the quantities of edible seed available for human collection. Because female plants and their seeds are the subsistence item important to hunter-gatherers, the following discussion focussed on this portion of the population.

Sex Structure

Although cycad plants are sexually dimorphic, having male and female plants, Beaton incorrectly inferred that plants of both sexes bear edible seeds that vary in size but were usually large and contained a moist kernel (Beaton 1977:139-40). However in all genera male cones do not produce an edible ovule (seed) but instead only produce pollen, while females in all genera produce edible ovules (seeds) (Figure 11-1, Figure 11-2, Figure 11-3) (Hill 1984:3; Jones 1994:15). The size of female seeds varies by species (Jones 1994). Male plants are important to hunter-gatherers as they produce the pollen to fertilize the female seeds and allow the development of female seeds to the ovule (edible seed) stage. However, hunter-gatherers are concerned with the seeds derived from female plants in subsistence. Because Beaton never clarified these points, there is the incorrect implicit argument that seeds of both sexes were used in subsistence.

Another important factor affecting seed availability and production is the ecological bias towards male plants in Macrozamia populations. This has been identified in both Australian and overseas populations (Ornduff 1985; Tang 1990:372; Vovides 1990:1539). The bias is not easily changed through hunter-gatherer manipulation, and suggests that differences in sex ratios have occurred in most Macrozamia populations through time. Ecological theories suggest that male biases have a range of causes, including genetic mechanisms promoting the production of male seeds, extensive time periods required for the growth and maturation
of female plants, predation affecting the edible coat and kernel of female seeds, the development of sex biases due to disease, environmental or weather conditions (discussed below), differential survival of males and females prior to and after sexual maturity, the sexual maturation of male plants before females, and a greater frequency of males producing reproductive organs than females (Tang 1990:372; Ornduff 1985:395; Vovides 1990:1539). However, the sex ratios in cycad populations, although showing some variability, tend to be more equal (Clark and Clark 1987; Newell 1983; Ornduff 1985, 1987, 1989, 1991b, 1992, 1993).

Age Structure

In most Macrozamia populations, including *M. moreii* in the CQH, plants in five life stages can be found: seeds, seedling, juveniles, non-coning adults (immature and mature) and mature coning adults (Negron-Ortiz et al. 1996:607). The age structure of populations are influenced by three main factors: 1) the time taken to reach sexual maturity, 2) environmental factors influencing successful recruitment of seedlings into populations, and 3) the survivorship of seedlings and plants to reproductive age. The three main effects of age structure in relation to the hunter-gatherer collection of seed are 1) seeds are produced by mature female plants, 2) populations are severely affected by death in all age groups, but particularly adult females, and 3) environmental factors can change population age and sex structure several times with a generation.

The age structure of female populations is an important variable in cone production, as only mature female plants produce edible seeds when they are sexually mature. The time taken to reach sexual maturity differs between genera and sexes, but generally male plants in most genera reach maturity faster than females (Ornduff 1992:40). Generally, both genera spend the first part of their lives developing a crown of leaves, and it is not until the plant has reached a certain size that the stem begins to develop (Watkinson and Powell 1997:346). Seed production begins in the second phase of the plant’s life cycle, once it has reached a large enough size (Clark and Clark 1987:137; Ornduff 1989, 1990, 1992:40; Tang 1990:372). In *M. moreii* female plants take an average of 50 years to reach reproductive age (Jones 1994).

However, there are several environmental factors which can substantially alter the recruitment of seedlings and their survivorship to reproductive seed bearing age in populations. Common environmental factors include drought, cyclones, fires and seed
predation by animals and humans. These factors act to destroy or damage seeds and seedlings and reduce survival rates, preventing them from attaining adulthood (Deghan et al. 2004:80; Demetrius et al. 2004; Farerra 2004:308; Huang et al. 2004; Jones 1994; Ornduff 1992:43; Tang 1990:372; Vovides 1990:1535; Zhang et al.1997). Together or individually, these environmental processes can lead to the consistent loss of young plants from populations, and lead to substantial changes to population ecology and evolution within and between populations and within and between regions (Zhang et al. 1997:15). However, adults are not immune from these processes either. Studies in Australia indicate extreme variability in age distribution is possible, even within local regions (Ornduff 1985:396). For example, some populations may be dominated by juveniles, or adults who have not yet reached reproductive age, or plants at reproductive age, or some combination of these (Watkinson and Powell 1997:343).

Two population studies and one simulation model illustrate the effects of the extensive periods taken to reach maturity, the high death rate of immature individuals and the slow rate at which the plants are replaced in populations. Studies of two cycad genera indicate that less than half of a seed cohort survives to maturity in natural conditions, with 43% of Dioon edule seeds and 46% of Zamia integrifolia surviving to maturity (Ornduff 1996:1006; Vovides 1990:1537). Simulation studies on species of Encephalartos in Africa indicate that populations can only survive a low percentage (5% or less) of adults being killed, with most populations experiencing this level of attrition either periodically or annually (Raimondo and Donaldson 2003:354).

**Cycle of Seed Production**

Macrozamia are characterised by temporal variation in the frequency of seed production by females. Vorster has called cycads "notoriously recalcitrant reproducers" (1995:379).

Production of cones can be variable and related to 1) masting and non-masting years, 2) the proportion of populations reproducing in masting and non-masting years, 3) the numbers of female cones produced by plants in non-masting and masting years, and 4) the time taken to produce edible seeds. These four variables have important implications for hunter-gatherer uses of the plants and seeds.

There are two temporal patterns of plant seed production. "Mast seeding", "mast fruiting" or "masting" describes the phenomena of synchronous high levels of cone production within a plant population in one reproductive season, followed by an interval of several years of "non
mast years” where few seeds are produced (Ballardie and Whel 1986:100; Hill and Osborne 2001; Koenig et al. 2003; Kelly and Sork 2002; Newell 1983; Ornduff 1990, 1991a; 1992, 1993; Vovides 1990; Zhang et al. 1997:20). Mast seeding is an irregular and relatively rare event in most Macrozamia populations, and the temporal and spatial frequency of seed production can be as long as 15 years. However, most Macrozamia species produce one or more stroboli every two to six years (Jones 1994:15; Negron-Ortiz et al. 1996). Occasional episodes of mast coning provide sufficient recruitment to allow populations to persist. The restoration of starch reserves requires several years. During this period cones are not produced (discussed further below) (Negron-Otiz et al. 1996:613; Ornduff 1985:393; 1991b:203; Tang 1990:373; Vovides 1990:1536; Watkinson and Powell 1997:342). The seeds produced in non-masting and masting periods can be variable because the quantities of seeds produced are related to the density and maturity of female plants in the population.

**Masting Production**

In mast years, it is evident that a marked difference occurs in the proportion of the population that can produce seed, although it can still be variable. In masting populations of *M. communis*, approximately 70% of the plants produced seeds, in contrast to a population in a non-masting year, in which 1-21% of the population produced seeds (Ornduff 1990). Over 30% of the population of *Zamia pumila* produced seed in a masting year, with marked reductions in the proportion of the population producing seed in successive events (10% falling to 4%, then rising to 25%) (Negron-Ortiz et al.1996:612, see also Clark and Clark 1987:138). These studies indicate that 1) not all mature plants in a population produce cones in a mast reproductive episode, 2) the proportion that produces seed in non-masting seed production varies from year to year, and can be separated by intervals of several years (Ornduff 1989), and 3) that plants in the surrounding population may not be participating in the mast event (Ballardie and Whelan 1986:101).

**Non-Masting Production**

Lengthy periods of non seed production after masting events are related to the time required to recoup the nutrition stores expended in seed production, as energy expenditure in female *Zamia* sp. plants can be 14 times those of male plants (Clark and Clark 1987; Negron-Ortiz et al. 1996:613; Ornduff 1985:393, 1991b:203; Tang 1990:371-373; Vovides 1990:1536; Watkinson and Powell 1997:342). Studies of Macrozamia seed production in non-masting...

The relative productivity of species and individuals can vary. The average number of seeds contained in stroboli of Macrozamia plants varies between species, and can range from 100 to 300 (Jones 1994; Kennedy 1993; Ornduff 1990). The mean productivity (and relative contribution) of seed can also vary per individual plant (Buonaccorsi et al. 2003:224; Zhang et al. 1997). The minimum number of cones produced by a female plant is one, and the maximum is three, although a maximum of eight has been observed in *M. moreii* (Jones 1994). Large robust female plants, and those plants located in good environmental conditions can produce either single or multiple cones in successive reproductive events in non-mast years (Baird 1939; Clark and Clark 1987; Ornduff 1987, 1990, 1991b:206; Tang 1990:372; Appendix Table A-46, Appendix Table A-45).

**Local Environmental Conditions**

The general mechanisms stimulating masting and incidental seed production in non-masting years are beginning to be understood. Plants appear to vary production in tandem with environmental conditions (Kelly and Sork 2002). Three of the most important variables affecting the regularity of seed production have been identified as: 1) environmental position, 2) rainfall, and 3) fire.

Studies have indicated that coning frequency is reduced in populations in heavily shaded environments (Clark and Clark 1987; Marler 2004), as well as in areas where soil nutrient content is low (Tang 1990:373). Comparisons between the coning frequencies of plants growing in different soil substrates indicated that *M. riedlei* populations growing in lateritic soils were smaller and produced fewer cones than plants growing in rich soils of the coastal sandplains (Baird 1939; Ornduff 1985). Other weather conditions, including the lack of drastic events (fire factors affecting leaf production e.g., cyclones and drought) are also important.
Frequency and Intensity of Rainfall

Variability in the production of seeds in mast and non-mast years has been found to closely correlate with rainfall (Ornduff 1992:43; Tang 1990:373; Vovides 1990). Global patterns of masting in 570 different species of perennial plants indicate that variability in seed production in the Southern Hemisphere is related to rainfall variability (Kelly and Sork 2002). As discussed in Chapter 3, the climate and rainfall in the CQH region today is variable and the region is frequently exposed to extreme weather events (Bell et al. 1989; Dick 1964). Given this information, palaeoenvironmental data also suggests that seed production over the last 4,000 years may have been variable (discussed further below).

Female plants in high rainfall regions, or growing in artificially watered gardens, have been shown to grow and mature more quickly, produce cones more frequently, and produce more cones per plant per seed production event (masting or non-masting) than plants in less advantageous positions (Jones 1994:56; NPWS 1997:4; Ornduff 1985; Whitelock 2002). Several researchers in Australia and overseas have noted the relationship between water, seed production, and better seedling survival (Grobbelaar et al. 1989; Vovides 1990:1540). In Australia, this has been noted by Baird in Western Australia for M. reidlei in artificially watered gardens which caused the production of large female cones every alternate year (Baird 1939:156), and also by Ornduff for separate populations of M. reidlei in Western Australia, with much increased frequency of cone production occurring every two years. I also noted that increased coning frequency occurred in artificially watered populations of M. moreii in the Australian Capital Territory and in Queensland. Studies also indicate that plants respond to rainfall after extended periods of drought by producing seed (Ornduff 1985). Ornduff suggested a possible increase in the proportion of female plants also might occur in high rainfall areas, as he noted that well watered environments contained 33% more female plants than other study sites in the same region (Ornduff 1985:396). It is possible that variation in sex structure and coning frequency occurred in populations over the last 8,000 years of variability in precipitation in the Holocene, this is discussed further below.

Responses to Fire

Fire is an important feature of the Australian ecosystem, and it is accepted that fire has been a major tool in Aboriginal land management practices for several millennia (Bowman 1986, 1998, 2000; Bowman and Brown 1986). In addition, many plants have adaptations to survive fire; some even require it or the “smoke water” produced after rains, to reproduce,
release seeds, and seed germination and growth (Dolva and Scott 1982). It is a reasonable assessment that fire was part of the landscape ecology in CQH. Many species of cycads live in fire climax habitats, and experience frequent and infrequent fire periodicity. Although cycad plants have some tolerance to fire (Brenner et al. 2003:446; Hill and Osborne 2001; Jones 1994; Keppell 2001; Negron-Oritz and Gorchov 2000:660; Negron-Oritz and Hill 2003:21), the available ecological data suggests: 1) that hunter-gatherers could not always count on the quick production of cycad seed bank after fire, 2) the frequent application of fire would always result in coning events, and 3) that population structure may become radically altered as a result of firing populations. Plants often do not produce reliable responses to fire.

Unfortunately, there are no direct studies available concerning the effects of fire frequency in *M. moreii* populations in the CQH. However, a growing body of literature is becoming available analysing the effects of fire frequency and intensity in closely related species. A review of the literature suggests several effects of fire on populations.

Studies indicate that the mechanism causing seed production in response to fire is due to the fire acting as a mineralizing agent, causing the transformation of organic nitrogen into inorganic form (Hobbs and Schimel 1984:402). Collaroid roots of *Macrozamia* sp. contain Cyanobacteria, which fix nitrogen (Fischer and Vovides 2004; Grobbelaar et al. 1986; Grove et al. 1980; Halliday and Pate 1976; Negron-Oritz and Gorchov 2000:667; Ornduff 1991a, 1992:43; Vovides 1990). Studies have indicated that nitrogen mineralisation is greater in burnt populations, and that levels of increased nitrogen persist after the fire (Hobbs and Schimel 1984; Grove et al. 1980). Fire also produces a range of beneficial effects that can lead to cone production in favourable conditions, including the opening of canopies, release of soil nutrients, improved microbial growth in soils, increased light levels and reduction of competition (Hobbs and Schimel 1984; Ornduff 1990b:97; Tang 1990).

Some reports indicate cone production has been stimulated, and possibly synchronized, in both male and female plants in the same year, or in the year following occasional bushfires (Baird 1977; Dyer 1965; Grove et al. 1980; Grobbelaar et al. 1986, 1989; Hall et al. 2004:335; Ornduff 1985, 1990; Pate 1986; Tang 1990:372; Vovides 1990; Znuckel 1995:287). Some studies indicate that cone production after fire in some Australian species may be stimulated, particularly in *M. reidlei* (Baird 1939, 1977; Pate 1986), and *M. communis* (Beaton 1977, 1982). In populations of *Z. pumila*, fire resulted in a three-fold increase in seed production (Tang 1990:372).
However, other reports indicate that fire may inhibit seed production. In two separate studies, Ornduff showed that populations with the lowest proportion of reproductive individuals were also the only two with evidence of burning within 12 months of the sampling period (Ornduff 1985:397, 1990). In Tang’s study of *Z. pumila*, 8% of the population remained dormant after they were damaged by fire (Tang 1990:369). Ballardie and Whelan reported that masting in *M. communis* populations did not occur after fire (1986). Studies also indicate that there may be long resting periods of plants after coning events induced by fire, either equal to or longer in duration than the resting periods in unburnt populations (Grobbelaar et al. 1986; Negron-Oritz and Gorchov 2000:660; Ornduff 1980:396; Znuckel 1995:287). While seed production occurred two years following fire in *M. reidlei*, significant periods of non-production occurred in other regions for the same species four years following fire (Grove et al. 1980:271). In addition, fires may not encourage seed production if the plant is already devoting energy to seed production (Ornduff 1991b:206).

**Fire Frequency**

Recurrent fire frequency can be detrimental as plants use available starch reserves in the production of leaves during the first few months and the first year following fire (Baird 1977; Dolva and Scott 1982; Grove et al. 1980; Ornduff 1991b, 1992:42; Znuckel 1995). If fire regularity is high, the plant is confined to the production of leaves (Baird 1977; Dolva and Scott 1982; Grove et al. 1980; Ornduff 1991b; Znuckel 1995) (see Figure 11.4, Figure 11.5). A marked reduction in leaf production was also reported by Grove et al. (1980) and Ballardie and Whelan (1986) in their studies of *M. reidlei*, and also in *Z. pumila* after fire (Tang 1990:372).

A study of the effects of fire frequency on population vigour and seed production was conducted in African *Encephalartos laevifolius*. Populations were burnt every two to three years in late summer, and once every ten years, and the results were compared to populations which were not burnt. The results indicated annual or variable burn frequency over ten year period resulted in seeds and seedlings being killed. A burn frequency of two to three years in late summer, or no burn at all, had the best effect on population vigour, where seeds were produced after the burning event (Znuckel 1995:287). In some situations fire produced coning events producing large numbers of seeds but very little seed production in the years after fire (Hill and Osborne 2001). Similar effects of fire frequency on population vigour
structure and reduction in seed production were observed in two geographically separated *C. armstrongii* populations in the Northern Territory (Watkinson and Powell 1997:348).

The periodicity in which fire has been used may affect the frequency, or even the generation of cones in some populations (Ornduff 1990:92). Ornduff’s study in two populations of *M. communis* at Morouya, 11 years after Beaton (Beaton 1977) illustrates issues of fire frequency and seed production variability. Ornduff found that the females in one population, which was not fired, produced “enormous” quantities of seed in a masting event, but other populations, which had been burnt, did not produce any seed. Ornduff suggested that cone production in the second population was suppressed as a result of the two to three year frequency of controlled burning resulting in repeated defoliation, but noted that even in the absence of regular burning cone production appeared to be sporadic (Ornduff 1990:97).

**Fire Intensity**

The intensity of a fire event can also have detrimental effects on seeds and population structure (Ornduff 1990). Research indicates that high fuel loads can lead to severe intense fires that damage or kill seeds on the ground, kill cones on plants, kill seedlings in unprotected areas and kill underground stems, kill older plants and increase susceptibility to insect damage, and kill insect pollinators and animals involved in dispersing seed (Gibbons and Taylor 2003:18; Negron-Oritz and Gorchov 2000:660; Vovides 1990:1542; Znuckel 1995:291). This kind of disturbance can disrupt the regeneration of populations and change the population size and structure, affect survival, fecundity, growth and morphology. Population recovery may be slow or impossible, resulting in the extinction of some populations (Higgins et al. 2000; Hill 2003:21; Negron-Oritz and Gorchov 2000:659; Raimondo and Donaldson 2003:345; see also Relgua 2004).

Several studies have been conducted concerning the effects of intense fires on cycad populations in the Northern Territory. Here, fire frequency has increased as a result of land management practices and the occurrence of annual intense late season fires which now threaten cycad populations (Hill 2003:21). A study of *M. macdonnellii* in the Northern Territory indicated this species was also becoming vulnerable to extinction due to the increased incidence of extensive hot fires and reduced incidence of cool fires (NPWS 2002:2). Several studies of *C. armstrongii* in the Northern Territory suggest catastrophic effects may follow high intensity fires in this population. Studies suggest adult stem mortality can be over 50%, and seed mortality was increased thorough the destruction of
existing seed banks, and a reduction in seed production in the same year following fire (Gibbins and Taylor 2003:16-18, NPWS 1997:14-21, NPWS 2002; Ornduff 1992:40; Watkinson and Powell 1997:348).

Responses to Sustained Collection/Predation

Archaeologists have assumed that the collection of large numbers of cones and seeds from plants can continue indefinitely without adverse effects (Beaton 1977, 1982; Beck et al. 1988; De Luca 1990; Donaldson et al. 2003:39). However recent studies on the impacts of modern collection practices have indicated that continual collection pressure on female plants and their seeds in wild populations causes pressure on plant population structure, maintenance and recruitment. This reduces the long term survival of populations, and in some cases, causes the extinction of local populations as all Macrozamia only regenerate from seed, depending on recruitment from seeds for population stability and growth (Boroughs 2003; Donaldson et al. 2003; Gibbons and Taylor 2003; Ornduff 1990:97; Raimondo and Donaldson 2003:345; Vovides 1990; Walters 2003). As seed production and plant maturity can take time, recovery can be slow or impossible (Raimondo and Donaldson 2003:345).

Some studies of the effects of seed collection have been conducted in Australian and overseas species. Ornduff suggested that in long term seed collection by humans might result in an absence of recruitment in *M. communis* populations (Ornduff 1990:92) and cycad populations (Whitelock 2002). A study in the *M. macdonnelli* populations of the Northern Territory indicate that populations are in decline in part from uncontrolled seed harvesting (NPWS 1997:3, 12). Raimando and Donaldson developed a simulation model of seed harvesting on *Encephalartos* sp. They suggest that harvesting seeds at low levels (10%) on an annual basis would not adversely affect population growth (2003:352). Because of these issues, NPWS restricts the collection of cycad seeds from the wild to no more than 50% of the total production in a harvest area in one year (NPWS 1997:8; NPWS 2001). This suggests that hunter-gatherers may have had to apply similar collection strategies to ensure the long term survival of the plant resource.

Implications for the Human Use of *Macrozamia*

It is clear that neither seeds nor populations of *Macrozamia* are easily managed as a crop as argued by Beaton. The plants are not amenable to common forms of horticultural
manipulation or intervention as have been suggested for other plant resources in Australia (e.g., yams: Hallam 1984, 1989; Hynes and Chase 1982; see also Gott 1982, 1984). *Macrozamia* sp. cannot propagate by suckering, and therefore manipulations of population structure cannot be achieved through replanting stems or leaves. Planting of seeds is also unlikely to produce increases in female plants as the sex of the seed is unknown at the time of planting, and the significant time periods involved before a cone is produced (Jones 1994). Even if planting was successful, the high juvenile mortality rate of 50% indicates that little immediate effect would be generated. It may take several generations of hunter-gatherers to produce effects through planting because of the exceedingly slow growth rate.

Water is a key factor promoting seed production; however it is unlikely that hunter-gatherers in the CQH were able to water plants. It remains possible that seed production, and increase in the relative proportion of female plants. This may suggest that productivity may have been higher in periods of high effective precipitation (EP) prior to 4,000 years BP, and in some well watered locations.

It is reasonable to assume that fires were part of the CQH environment, whether or not they were anthropogenically lit. It is probable that fire, used for other purposes in the region (e.g., Jones 1969) created changes in *Macrozamia* populations. Current data indicates that low intensity “cool fires” prior to the wet season, at intervals of two to three years, particularly in well watered environments, promote the most beneficial effects to seed production. This kind of fire schedule (early dry season, low intensity fires) seems to have been preferentially applied by Australian Aborigines. This avoids the excessively hot fires that are disadvantageous to cycad communities (Hill and Osborne 2001; NPWS 1997, 2002). However, as discussed above, even if hunter-gatherers applied fire in this manner, it may not have always resulted in increased seed production. Indeed, firing would have produced extensive dormancy periods thereafter, and populations may have suffered fire related attrition. Research suggests that mast seed production may have been more regular under normal environmental conditions. The annual fire frequency suggested for other areas of the continent suggests that this level of burning may have been detrimental to seed production in *Macrozamia*, unless mosaic or carefully controlled burning occurred (see Hill and Baird 2003), but even then seed production was not guaranteed.

Given that hunter-gatherers could process and consume both fresh and aged seeds, there are two properties of the plant that would influence the way in which they might be used by
hunter-gatherers: 1) seeds have a long residence time, and 2) seeds are suitable for storage for extended periods of time.

The fleshy outer sarcotesta layer covers the outer opening of the seed, preventing pollination of the embryo inside the kernel and prevents germination of the seedling (Negron-Ortiz et al. 1996:611; Vorster 1995). Germination usually only occurs after the outer fleshy layer has rotted away (Negron-Ortiz and Gorchov 2000:660). The temporal length of the “after ripening period” varies with the species, but can be several months (Jones 1994:15). Macrozamia seeds have a after ripening period of six to 12 months where the seed remains viable (Broome 2002). The after ripening period is also useful for hunter-gatherers as it allows longer environmental residence times of the seeds and extends the period available for collection (Vorster 1995).

The environmental residence time of female seeds varies by species (See Burnham 1993; Jones 1994). In M. moreii, female cones and seeds have a long residence time in the environment. The time between cone initiation to cone breakup can be as long as 18 months (Jones 1994; compare with L. peroffskyana, Figure 11-6). Seeds from earlier reproduction events can become trapped in the crowns of plants and can remain for several seasons (Ornduff 1990:93; Figure 11-7, Appendix Table A-16). The percent of individuals exhibiting evidence of seed production in the current and past season ranged from 0 to 50% in M. communis (Ornduff 1990:95), and 0 to 33% in M. reidlei (Ornduff 1985:395). Such environmental residence is useful for humans as it greater seed numbers to be collected (Vorster 1995). Seeds from earlier reproductive episodes can also remain on the ground surface beneath parent plants in large numbers (Watkinson and Powell 1997:345). In one study, up to 170 seeds were found beneath plants that had an annual production of 80 seeds. This can occur both in the presence or absence of seed predators (see Chapter 6 and below). Seeds can have long residence times beneath the plants (Baird 1939:155; Ballaride and Whelan 1986; Tang 1990; Watkinson and Powell 1997:347).

Although Australian archaeologists have stated that some of the temporal unpredictability of Macrozamia seed production may be artificially extended through storage of the seeds, none state how this can occur (Beaton 1977; Beck et al. 1988, citing Mike Morwood pers. com). Specialists working with these seeds have become familiar with techniques of seed storage.

The after ripening period is the variable that allows the nut to be stored. Two methods of storage of the seed have been suggested by the literature and in experimental trials: storage
of the seed (with and without sarcotesta attached) in moist or dry conditions. However, seeds stored with sarcotesta can be stored for longer periods than seeds without sarcotesta.

If seeds with sarcotesta are kept in a moist environment they can remain viable for several years provided the outer flesh is kept intact, but they lose viability in a few months once outer flesh has been removed. Fresh seed is kept viable by storage in damp environments (moss, leaves) (Hill 1984:21). Seeds with sarcotesta that were kept in a dark, dry environment were also found to keep well. Seeds used in the experimental trials were stored in cardboard boxes in laboratory conditions (without air conditioning). Seeds were still viable for four years after collection. This suggests that similar storage potential could have existed if seeds were protected from the elements and predation.

Even if seeds with sarcotesta have begun to desiccate, seeds can still be used. The fleshy outer cover is thought to be a protective barrier keeping the inner kernel moist and protecting it from desiccation. Seeds are susceptible to the absorption of moisture, and dehydrated seeds, which rattle when shaken, can be rehydrated by soaking the seed (and or kernel) in water for a few days. This can also extend the usability of the kernel for one year (Broome 2002) Seeds can become desiccated within three months when stored without sarcotesta.

**Ecological Evidence for *Macrozamia* Use in the CQH Sites**

The *M. moreii* data from the three CQH sites suggests the collection of seeds and cones from the local area around the site at the time of site occupation (Table 11-3). Taphonomic evidence on the specimens from the CQH sites was the most informative line of evidence and was analysed in relation to available ecological data. Ecological and taphonomic data can be used to suggest the possible population sizes of Macrozamia around the sites over the last 4,000 years and at the time of occupation, and the type of seed production event at the time of occupation (masting or non-masting). The taphonomic evidence includes 1) rodent gnaw data, and 2) frequency of weathered specimens (Table 11-4).

The frequency of weathered and fresh seeds in the natural population was compared to the archaeological population. The results suggest that weathered seeds, remaining from past coning events, were available for collection. The striking patterns of rodent flesh removal and gnawing into the shell obtained from ecological studies were compared to the archaeological sample as a possible indicator of the timing of human collection strategies.
Both the rodent and weathering evidence for the three sites suggests the collection of seeds from plants in both masting and non-masting years.

At Wanderer’s Cave, seeds between 35-40 cm depth appear to match masting years, with the entire sample (although small, $N = 5$) being weathered seeds with rodent marks. There is a marked change between 15-35 cm depth where the collection of stroboli from plants in non-masting years is suggested. During this period, rodent toothmarks were of very low frequency, with increased frequency of rodent breaches of the shell, which is consistent with non-masting years. The seeds in the upper 10 cm of the site display a high frequency of rodent marks, and substantially high weathering rates of seeds. High rates of rodent gnawing in the upper 10 cm of the deposit may indicate the collection of fresh seeds from a masting event.

At Rainbow Cave, variations in seed collection from masting and non-masting periods through time are also suggested. The relatively high rates of rodent toothmarking between 25-35 cm depth are indicative of masting. However, there is a marked change between 5-20 cm depth where seed collection from non-masting events is indicated. In the upper 10 cm of the site masting events are indicated based on rodent gnawing patterns.

At Cathedral Cave, the majority of seeds seem to be collected in non-masting phases of the plants production. Only six levels of the site have data which support masting collection, all the evidence is clustered in U6 and U7, which are both located nearest to the *M. moreii* plant in the site.

In summary, the presence of both fresh and aged seeds in the archaeological sites is a pattern that is consistent with modern ecological data for seed availability in *Macrozamia* populations. This suggests fresh cones seem to have been collected off plants, and isolated seeds from prior coning events are also collected. Given people are using seeds in masting and non-masting periods, it suggests that the utilisation of the resource and the occupation of the sites are not contingent on masting events in *Macrozamia* populations. The level of seed production in female plants may be predicted in advance of cone initiation in two ways 1) increased masting potential after increased rainfall, and 2) observations of cone initiation in populations while travelling in the region. As described above, seed availability in non-masting years can still be plentiful, and be utilised by family groups.
To further investigate if the human occupation of the region was timed to take advantage of increases in seed production after rainfall events, a comparison was made of the timing of both masting and non-masting events and palaeoclimate data (Table 11-5). The results indicate that in the last 1,200 years, most of the seed production events may have occurred in relation to increases in effective precipitation (EP) (as is indicated by current ENSO data, Schulmeister and Lees 1995, and phytolith data, Bowdery pers. com. 2005, Genever et al. 2003), with some seed production in non-masting events in the CQH. The data also indicate that both masting and non-masting seed production occurred as a result of local climatic events which brought rainfall into the region, as indicated by fluvial events for both Cathedral Cave and Nogoa River (Bell et al. 1989).

Wider Implications

The ecological, archaeological and taphonomic data suggests that M. moreii were not easily managed, and by extension calls into question the idea that other genera were easily managed. Ecological data suggest that there are going to be similar constraints on the human use of cycads and Macrozamia in any arid and semi-arid environments across Australia.

The ecological history of Macrozamia since human occupation of the continent is likely to have been complex. Palynological evidence suggests that firing the landscape has occurred since 60,000 years BP (see Kershaw 1970, 1971, 1974, 1981, 1984, 1986, 1995; Kershaw et al. 1993). This would have created changes in Macrozamia seed production and population structure and have flow on effects in the survival and density of other species using cycad seeds, including generalists (e.g., possums, rodents) (see Liebhold et al. 2004; Schmidt 2003) or specifics (insect pollinators, see Terry 2001; Wilson 2002).

It is possible that variation in sex structure and coning frequency occurred in populations as a result of variability in effective precipitation in the Holocene. The ecological and palaeoenvironmental data suggest potential variability in seed production in different species and regions of the continent over the last 7,000 years (Schulmeister and Lees 1995:12). Based on available data concerning El Nino patterns, masting events may have been more regular prior to 3,700 years BP, when effective precipitation and temperature were higher. In addition, based on differences in the timing of the impact of El Nino patterns (north-south differences across the continent) this might be reflected in archaeological sites, but in all environments variability may be indicated prior to 3,700 years BP. A sharp decline in effective precipitation after 3,700 years BP and an increase in climatic variability and natural
disturbances (floods, aridity, tropical cyclones) from 1,000 years BP to the present is likely to have had a significant impact on the age and population structures in cycad communities (Hirsch and Marler 2002:598). Drought especially may have reduced coning events, and seed and seedling survivorship (Negron-Ortiz et al. 1996:611; Vovides 1990).
Chapter 12: Discussion and Conclusions

...answers will not come from simply gathering more of the same kinds of data. Some new ways of working with archaeological records are needed, as well as new perspectives on the data they yield (Stiner 1994:1)

...archaeologists must begin thinking about the reliability and validity of the measures employed to analyse their collections, rather than relying on precedent and tradition (Mason et al. 1998:319)

This thesis argued for, and demonstrated the importance and potential of, a positively focussed, ecologically grounded, taphonomic analysis of archaeological sites in the Australian context. The taphonomic reanalysis of the sites has provided a better understanding of the factors that have affected the assemblages and offers quite a different account of human activity in the sites.

The analysis of the three sites in the CQH has provided an alternate view of the use of Macrozamia, built on ecological and taphonomic data. In addition, the investigation into the role of taphonomic site formation processes on the structure and content of the archaeological record of three sites in the CQH have significant implications for the original interpretations of mid Holocene change in the region, and Australia. In the process it underlines the danger of side stepping the development of detailed, taphonomically grounded accounts of archaeological sites, and making premature inferential leaps to high level models of behavioural change. The thesis, although raising critical issues in methodological approaches to the interpretation of the archaeological record, represents a step towards the integration of taphonomic approaches into mainstream Australian archaeological research, and proves the value of models created using both ecological and taphonomic data to interpret the past.

High level models and taphonomic research in Australia

Reassessing "The Seeds of Change"

This thesis demonstrates that using taphonomic evidence to challenge hypotheses leads to more strongly warranted inferences regarding past life relations that produced certain
configurations of taphonomic traces in sites (Gifford-Gonzalez 1991:218). The research carried out in this thesis changes our understanding of the human use of the three rockshelter sites in the CQH and calls into question higher level accounts of the use of the sites within the region. Taphonomic and ecological data were used to test claims of a mid-late Holocene ceremonially based occupation of the CQH.

As discussed in Chapter 11, the original arguments concerning the intensive use of Macrozamia could not be supported. Ecological, taphonomic and archaeological methods were applied to investigate the likely period of collection, the range of taphonomic actors and processes acting on the remains, and the estimation of the quantities of seeds using MNI, MNE and density estimates. The MNI estimates in particular indicate that very low numbers of seeds were collected over the last 4,000 years in the CQH sites, and as such, do not support the argument for the ceremonial use of these seeds by several hundred individuals for two week periods. In addition, ecological data indicates that humans collected available Macrozamia resources when they were in the local region and at specific sites, by collecting entire cones on plants, isolated seeds which had fallen beneath the plants, or both. Interestingly, rodents were less of a taphonomic factor than anticipated, while taphonomic attrition to seeds caused by insects was an unexpectedly useful line of information. The new interpretation of the use Macrozamia remains from the CQH sites also has implications for high level models which have used these arguments to support the idea of wider changes in Aboriginal societies in the mid Holocene.

The reappraisal of arguments about the role of Macrozamia in the CQH has had an impact on our understanding of CQH but also raises important conceptual issues for archaeologists in general. How do archaeologists characterise a resource as “low yield”; an environment as “marginal” or the use of specific resources as opportunistic or planned? The answer lies in the detailed understanding of the properties of the resource itself. Without this ecological grounding, models are built on assertions or common sense views that are rarely going to be refuted by the fragmentary and ambiguous archaeological data. Ecological and ethnographic data, when used together, provide a much better understanding of the real constraints and possibilities offered by this resource on the inhabitants of the region. In particular, it is clear that there are a range of processing strategies available to humans based on the age of the nut and the deliberate use of fire to reduce toxicity and aid in the physical fracture of the seeds. This in turn undermines simple notions of Macrozamia, and more broadly, cycads, as high yield, low cost foods, or as easily managed and synchronised resources providing a convenient superabundance.
Reassessing Other Correlates of Change

It was also argued in Chapter 1 that most of the correlates that are traditionally seen as indicators of changes in the archaeological record may largely be a result of taphonomic processes. The results of the analyses of preservational biases and taphonomic processes support this position. Broad patterns of preservation or biasing factors can be identified within the CQH sites. The major taphonomic processes that operated in the sites were identified as dingoes, rodents, fire, floods and humans, which acted to variously create biases in the preservation of differentially modified specimens within the same class of evidence, and reorganise the archaeological components of the sites in the CQH. In many ways, these ubiquitous taphonomic processes acting within, and the taphonomic histories developed for, the sites in the CQH can be seen as representative of many sites within Australia.

The timing of the occupation of the three sites analysed here are all largely a result of the relatively late erosion of rockshelter sites in this region, which has created niches for human activity. However, sediments within these sandstone rockshelters began to form in conditions which create acid preservation matrixes (Webb 1992). As a result, this caused systematic and large scale biases in the preservation of organic remains, and particular classes of organic remains, preserving carbonised plant materials over uncarbonised ones, and burnt faunal remains over unburnt ones. Unburnt specimens showed high rates of in situ fragmentation. Neither the timing of the occupation of the sites, nor the changes in density of faunal and plant remains can be taken as evidence of intensification.

The original interpretation of the faunal assemblages in the CQH sites was argued as the result of human prey selection and modification. Dingoes have been a ubiquitous part of the landscape in the late Holocene Australia. A conservative analysis applied here, which underrepresented the true level of modification, indicates that more than 32% of the assemblages contained evidence of canid gnawing, digestion or both. This frequency of canid evidence on archaeofaunas of the CQH was consistent with other analyses of canid modified archaeofaunas (Hudson 1993:303). Very little evidence remained concerning the direct human action in the faunal accumulation of the CQH assemblages. A number of correlates were also identified for the CQH including denning, individual and pack hunting of Petrogales and Macropods, and the modification of humanly caught Macropod remains. The canid overprinting (and overprinting by a range of other processes) changes the
properties of the faunal remains as well, altering their vulnerability to mechanical and chemical weathering, fluvial winnowing and burning. It was unsurprising that minimal evidence for the human interaction with the faunal remains was identified, given Solomon's results (1985).

Faunal assemblages in Australia can be expected to be routinely modified by dingoes, and dingoes can be expected to regularly deposit faunal remains from their own hunting and denning activities into rockshelters, sediment traps preferred by archaeologists. The current notion of a broadening of the resource base, one of the major correlates of "intensification" could well be related to the emergence of the dingo, and its ability to adapt hunting strategies, and both generalise on a range of small, medium and large prey. Clearly, much further detailed work needs to be conducted concerning the sustainable hunting of Macropods by humans (Abbott 1980; Kohen 1994).

In addition, the resolution of the information in the CQH faunas was substantially modified by thermal modification. The identifiable heating of bone in the CQH is most consistent with incidental modification as a result of fires rather than deliberate burning of the bone in cooking. This has direct implications for studies of "intensity of site use" which typically use increases in burnt bones and other remains to argue or support their case.

The Value of Taphonomy in Australia

Australian archaeologists have only one choice if they are to tackle the kinds of questions and issues that have been raised regarding models of Australian prehistory. Australian archaeology needs to follow overseas examples and build up a methodological and analytical tool kit based on ethnoarchaeological, experimental and neotaphonomic research to critically examine the agents and processes involved in the formation of Australian sites and develop analytical techniques to answer Australian research problems. Archaeologists must produce more rigorous analyses of the components of the archaeological record, and their transformations, that recognise the various issues involved in the formation of the collection of remains they are analysing (Rossen et al. 1996:405). The aim is to enable archaeologists to generate more taphonomically sensitive interpretations of their data, within more knowable confidence limits.

Taphonomic methods and approaches have both positive and critical contributions to make to our understanding of the past. Critical taphonomy provides a series of cautionary tales.
concerning incorrect interpretations of data and models of various aspects of the past and methodological critiques of traditional approaches to archaeological analysis and interpretation. The negative aspects of taphonomic processes also are seen to concentrate on the “biases” created by processes (e.g., pH, burning). Critiques of theoretical and methodological approaches are important (Denys 2002) but analysts need to go beyond this to address solutions to the problems identified. Taphonomic modification is the rule rather than the exception.

Taphonomy has much more to offer than cautionary tales. While taphonomists have struggled to stress the positive outcomes of taphonomic approaches by emphasising information gain, there are few clear examples of the benefits of the approach. Taphonomic analyses aim to account for all of the key actors and processes that have acted within a site, and rather than focussing on identifying the exclusively human aspects of the site, it provides a much richer account of the events and activities that were occurring even when human beings were entirely absent. It encourages researchers to ask new questions and analyse new lines of evidence. Information about the activities of rodents or denning dingoes is information useful to understanding the specific local history of the site. All archaeological data is taphonomic in this broader view. Recognising and understanding the activities of the wider range of actors and processes increases the available knowledge, and provides analysts with a better idea of the confidence they can have in patterns or features in the archaeological record.

Taphonomic analyses, especially when combined with rigorous methodological approaches, allow us to more carefully consider the data in the archaeological record and its ability to reflect human behaviours. The development of taphonomic and ecological knowledge to understanding the record leads to deeper knowledge of the actors and factors in the record, and allow us to interpret the record in more detail. Snapshots of the real human past can be created using taphonomic data. Taphonomic analyses are important even if humans are not much associated with a site's formation, as this can still tell us about the use of space in local and regional environments (Gentry-Steele and Carlson 1989; Hill 1989b:287)
Building Positive Taphonomy in Australia

Taphonomy, like Australian archaeology, is a comparatively young discipline. It is clear that taphonomy does not offer a quick fix for the challenges facing Australian archaeologists. The Australian context is sufficiently different that basic research is required in order to lay the foundations for an effective Australian taphonomy. This is particularly true if taphonomic analyses are to move beyond the critical and provide a positive approach allowing archaeologists to say more about the past. Building up Australian taphonomic data allows us to interpret taphonomic processes and build models based on Australian actors and processes, and develop positive informed, confident accounts of the past, and with them, new understandings of Australian prehistory. The ability to generate good results from museum collections is a good indicator of the power of this approach.

In order to proceed, analysts must investigate 1) under what circumstances can the careful application of “universal” taphonomic processes investigated overseas be applied to the Australian context, 2) “datamine” relevant ecological data and carefully apply this to the archaeological context, determining cause:effect relationships of the behaviours of actors and taphonomic effects on specimens under study, and 3) draw on many other disciplines (e.g., palaeontology, geology, paleobotany, paleoecology, paleoentomology and forensics).

Investigation of Single and Multiple Stage Taphonomic Processes

The experimental approach has been instrumental in allowing analysts to understand several aspects of taphonomic processes and their effects on archaeological remains (Denys 2002; Lyman 1994). However, the vast majority of experimental studies are narrow in scope and investigate the effect of a single taphonomic process (e.g. burning). Given that archaeologists deal with palimpsest hunter-gatherer records, Australian archaeologists should be at the forefront of taphonomic research.

Taphonomists now realise that archaeological deposits and their components are never the result of only one taphonomic process, and may be the end result of a complicated interplay of a series of multiple and cumulative natural and human taphonomic agents and processes both during and after the occupation of a site (Bailey and Grigson 1987:17; Balme and Beck 2002:157; Behrensmeyer 1993:343; Bonnichsen 1989a:517; Erlandson and Rockwell 1987:51; Hassan 1987:1-5; Lyman 1994:40, 453; Marshall 1989:7; Murphy 1992:9; Nelson 248...

Some taphonomic processes can also be understood using relevant ecological data relating to the behaviours of non-human actors. Such data allows archaeologists to determine cause: effect relationships of the behaviours of actors and taphonomic effects on specimens under study. However, archaeological data needs to be carefully applied to the problems archaeologists face in interpreting the archaeological context.

To more completely understand the taphonomic processes arising from human behaviours, ethnoarchaeological and anthropological observations, while of variable quality, often contain useful information to consider taphonomic problems more closely (Lyman 1994:454). For example, these records often describe common behaviours in the treatment of animals, plants and stones, which allow the careful design of experimental programmes through which test the effects of variables. This allows the development of correlates useful to the interpretation of the archaeological record. However the ethnographic record also needs to be read with a critical eye.

It is clear that in the Australian case archaeologists need to more clearly determine the variety of behaviours of non-human actors, particularly more detailed analyses of the taphonomic correlates of dual patterned, hunter-gatherer dingo assemblages. The underlying assumptions and analytic methods concerning dual patterned archaeofaunal assemblages of humans and hyaenas in Africa are a useful starting point.

In addition, testing the particular effects of more “universal” processes in the Australian context would be valuable. This would include taphonomic studies of the modification of faunal, shell and eggshell components of the archaeological record. This means that analysts must be willing to perform experimental work on specific classes of data (e.g. cycads fracture differently to Macrozamia). The results of such analyses would also be useful for cross checks, and analyses of multiple taphonomic processes on different lines of archaeological evidence.

Future taphonomic research designs also have to combine agents and taphonomic processes to more closely mirror and understand the complexity of most archaeological accumulations. Such multi-factor analyses, and investigations into palimpsests tend to produce “positive taphonomy” because the results of these analyses bring the archaeologist much closer to the
conditions of the formation of the assemblage and help to identify other combinations of
taphonomic processes and effects that need testing. The investigation into the cumulative
effect of multiple processes in the Australian context is an important and necessary line of
research.

Learning from Overseas Contexts

However, experimental, actualistic and replicative experiments presently available must also
be carefully scrutinised. This includes assessing flaws in experimental designs, and
considering the comparability of the methods, interpretations, results and correlates.
Although the general method of taphonomic approach “is so obvious as to be unremarkable”
(Gifford 1981:397) there are significant issues in using experimentally defined “diagnostic”
criteria to test hypotheses/predictive models (Bonnichsen 1989a, 1989b; Hassan 1987:2).
Ascribing meaning to the archaeological patterns involves matching the observed
archaeological patterns and effects to actualistically observed patterns (Lyman 1994:455).
Testing hypotheses/predictions concerning taphonomic histories with data from modern
actualistic data is only as good as the range of actualistic data itself. Thus the analyst also
needs to perform a critical examination of experimental actualistic middle range research to
examine methodological and interpretive problems potentially affecting the cause:effect
relationships as experimentally defined.

Issues concerning the precise interpretive meaning of fundamental attributes and
interpretations of a number of taphonomic processes have been raised in the literature
(Lyman 1994; Denys 2002), for example cutmark experiments (Shipman 1981; Shipman and
Rose 1983; Fischer 1995) and temporal estimates from weathering data (Lyman and Fox
1989). Analysts need to consider these weaknesses in experimental design and
interpretation, and how they affect identification of trace effects on objects and their
interpretations of taphonomic histories. Other attributes of taphonomic modification used to
distinguish natural from cultural processes are equivocal when used alone, and confidence is
often strengthened when several correlates of the same taphonomic processes are used (e.g.,
thermal modification by colour and morphological changes), and comparative analyses are
made (Brett and Baird 1986).
Conclusions

Sequential and multiple taphonomic overlays on each line of evidence and each layer of each site create variability between archaeological assemblages (Kowalewski 2002:5). Jumping from “apparent” patterns in the archaeological record to high-level models short-circuits the kind of detailed, local, ecological and taphonomic studies needed to create more reliable and testable accounts of the past. It is clear that if archaeologists are to extract the full range of information locked in the archaeological record, they need to use of a range of different analytic methodologies and techniques from a number of sub disciplines. Only then can the interpretation of the meaning of, and information within, variations within and between sites be understood (Kowalewski 2002:5). Comparing variables relative to one another at different sites allows archaeologists to better understand similarities and differences in taphonomic agents and processes between sites or parts of sites, including the assessment of preservational biases, and evaluate the causes and meaning of regional archaeological variation (Behrensmeyer 1991:318). As stated by Martin et al.: “assessment of taphonomic histories is a daunting task...many of the current approaches to modelling will require extensive testing and revision, but we have only to learn from the process” (Martin et al. 1999:viii, italics in original).


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