Earth Mounds, Mussels and *Typha*:

Innovation in Aboriginal procurement strategies on the Murray River floodplain, Calperum, South Australia

By

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Abstract

This thesis investigates the mid to late Holocene lifeways of Aboriginal people living on the Calperum floodplain in the South Australian Riverland. In particular, the excavation and examination of six Aboriginal earth mounds located in three different contexts within the floodplain are explored. The evidence obtained from these earth mounds indicates that Aboriginal people adopted an innovative food production system at ~3800 cal BP. This system involved large scale earth oven cookery incorporating the use of river clay as a heat retainer material.

The behavioural change outlined above occurred at approximately the same time as the onset of reduced water flow and increased salinity within the floodplain linked to the El Niño Southern Oscillation (ENSO) related weather patterns. Ecological change led to a decline in the availability of terrestrial and aquatic food resources within the system of anabranch creeks, ephemeral lakes, billabongs, swamps and lagoons at Calperum. The decline in food resources likely provided the impetus for the adoption of an alternative source of nutrition culminating in the intensive exploitation of *Typha* rhizomes, and potentially other aquatic plant roots which were processed in earth ovens. Such activity was centred on specific sites adjacent to emergent macrophyte habitat in anabranch creeks and billabongs which gave rise to distinctive mounds that were established as required and used on a seasonal basis.

The data derived from radiocarbon dating and sediment analyses (including contents, grain size, magnetic susceptibility, loss on ignition, plant microfossil analysis, pH, colour and elemental profiling) has allowed insights into behavioural change within Aboriginal societies at Calperum. Such change includes the implementation of technical, socio-economic and cultural innovation, and a consideration of the role of women in addressing a disruption in local subsistence procurement systems. Furthermore, the data has enabled a consideration of both 'intensification theory' and the broadening of diets in relation to Aboriginal populations at Calperum, and more broadly within the Murray Darling Basin, from the mid Holocene.

Statement of Authorship

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and the research within will not be submitted for any future degree or diploma without the permission of Flinders University; and that to my knowledge and belief, does not contain any material previously published or written by any person except where due reference is made in the text.

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The article presents initial results and discussion of research data collected by myself and co-author AR. Sediment processing and analysis was done by myself. Radiocarbon analysis was done by co-author GJ. I planned and implemented the research design and provided stratigraphy diagrams, the majority of the text and tables and synthesis of the data presented in results, discussion and conclusion sections. Co-author CW provided 2 maps, IM provided a radiocarbon range graph and co-author RR provided sediment diagrams.

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Glossary and Abbreviations

^{14}C	Radiocarbon age
ALT	Australian Landscape Trust
BSD	Broad spectrum diets
BSR	Broad spectrum revolution
cal BP	Calibrated radiocarbon years before present (1950)
EES	Extended evolutionary synthesis
ENSO	El Niño Southern Oscillation
GDR	Great Dividing Range
ICP-MS	Inductively coupled plasma mass spectroscopy
IOD	Indian Ocean Dipole
IPO	Interdecadal Pacific Oscillation
ITCZ	Inter-Tropical Convergence Zone
Ka	1,000 years before the present
LIA	Little Ice Age
LiDAR	Light Detection and Ranging
LGM	Last Glacial Maximum
MCA	Medieval Climate Anomaly
MET	Macro-Evolutionary Theory
MDB	Murray Darling Basin
MHCO	Mid Holocene Climate Optimum
NCT	Niche construction theory
OFT	Optimal foraging theory
pXRF	Portable x-ray fluorescence
RMMAC	River Murray and Mallee Aboriginal Corporation
SET	Standard Evolutionary Theory
SAM	Southern Annular Mode
SPD	Summed Probability Distribution
TPQ	Terminus post quem
USO	Underground Storage Organ

Chapter One: Introduction

1.1 Introduction

This thesis reports on a comparative analysis of the excavation of six Australian Aboriginal earth mounds located within the floodplain environment at Calperum[1] Station in the South Australian Riverland (Figure 1.1). The study provides new data about Aboriginal earth mounds, which, coupled with a re-examination of existing data, contributes new information about changes in socio-economic and cultural behaviour associated with their use. This work therefore adds to the body of knowledge about Aboriginal societies in this region and contributes to wider debates about purported trajectories of socio-economic 'intensification', Aboriginal lifeways, socio-economic strategies and the introduction of broad-spectrum diets (see Hiscock 2008:265–266 for an overview on this debate). This thesis also relates the evidence from Calperum to broader theoretical discussions about Australian Aboriginal socio-economic practices during the Holocene.

The introduction of 'broad-spectrum diets' (BSD) into hunter-gatherer subsistence strategies has been hypothesised as a transition in the way that humans exploited resources during the terminal phase of the last glaciation in some places (Flannery 1969; Zeder 2012). Flannery (1969) introduced the concept of a 'broad-spectrum revolution' (BSR) to account for diverse phenomena (in terms of spatial, functional and chronological parameters) which emerged in the archaeological record at that time (Edwards and O'Connell 1995; Flannery 1969; Zeder 2012). As originally defined the transition included:

> …the addition of a number of previously largely ignored invertebrates, fish, water fowl, and plant resources to the diet of Upper Paleolithic foragers…

[and],

> …was set within the context of a demographic density equilibrium model that involved the overflow of population from optimal resource zones into more marginal ones (Zeder 2012:242).

[1] An Aboriginal word derived from the local Erawirung language said to mean 'a branch road or short-cut' (Tindale c.1934–c.1991). In this thesis I privilege traditional place names where available and appropriate. I also acknowledge that European place naming reflected the imposition of colonial power (Berg and Kearns 2009; see also Roberts et al. 2019:239).

The phenomenon has been variously attributed to the influence of intra-group social changes and the changing complexity of systems of social organisation, the introduction of new technologies, sedentary behaviours, demographic change, new food storage strategies and climate change associated with the terminal Pleistocene in western Asia (Binford 1968; Flannery 1986; Redding 1988; Rosenberg 1990, 1998; Straus 1977; see also Edwards and O'Connell 1995; Zeder 2012). The BSR became synonymous with dietary diversity, resource intensification and stress associated with population growth and resource availability; providing a conceptual framework for the domestication of plants and animals and the emergence of agriculture (Zeder 2012:242).

The purported introduction of BSD, in Australia, during the mid Holocene has been suggested to be the equivalent of the BSR as originally hypothesised by Flannery (1969) for the Euro-Asian context, albeit occurring considerably later (see Edwards and O'Connell 1995; Ross et al. 1992; Smith 1993; Veth 1987, 1989,1993; Veth et al. 1990 for perspectives on this debate). Further, BSDs have been posited to be part of an adaptive suite of responses by Australian Aboriginal peoples to environmental and/or socio-economic changes at that time (Edwards and O'Connell 1995; Haberle and David 2004; Lourandos 1983, 1985, 1997; Lourandos and Ross 1994; Pardoe 1995). Such responses have been argued to have included the occupation of previously marginal areas (for instance in arid regions of the continent) and/or the innovative exploitation of low trophic resources such as the greater use of seed grinding technologies and detoxification processes involving the leaching of toxic chemical components from nuts through immersion in running water and/or the application of heat (Asmussen 2009, 2010a, b; Ferrier 2015; Ferrier and Cosgrove 2012; Haberle and David 2004; Smith 1993). A further example of the innovative use of heat is the reported use of ground cookery for the preparation of rhizomes from wetland plants such as *Typha, Phragmites, Bolboschoenus* and *Triglochin* spp. that can require extensive labour input in management, harvesting and processing to provide the available nutrition (Bonney 2007:45–47; Gott 1982, 1983, 1999; Macintyre and Dobson 2008; Martin 2006, 2011).

Complex processing technologies probably enabled the mitigation of environmental risks in both intermittently occupied and established territories (e. g. arid and rainforest areas subject to adverse environmental cycles). The development of new stone-working techniques has also been argued to be an example of the implementation of innovative strategies in this context (e. g., Hiscock 1994). The intensive and repeated use of heat-retainer earth ovens for large scale processing of carbohydrate and fibre rich geophytes in specific locations in floodplain landscapes is an example of innovation through the repurposing of an existing technology, with excellent potential for assisting the establishment of a radiocarbon chronology for the consideration of BSD in Australia (Brockwell 2006a, b; Jones et al. 2022; Martin 2006, 2011).

Aboriginal earth mounds appeared in the Australian archaeological record, in a significant number of floodplain environments from the mid Holocene in discontinuous, widely separated northern, north-eastern and south-eastern regions of the continent (Figure 2.1), possibly in response to the onset of adverse climatic conditions and/or the emergence of new wetlands due to environmental change. Evidence of the apparent sudden emergence of earth mounds and continuity of use, at multiple locations across Australia, is provided by 164 previously published age determinations[2] (Berryman and Frankel 1984; Brockwell 2006a, b; Brockwell et al. 2017; Coutts et al. 1979; Godfrey et al. 1996; Johnson 2004; Klaver 1998; Martin 2006; Williams et al. 2008; see also Appendix Nine). A principal aim of this project was to contribute to and work to refine known earth mound chronologies (e. g., Balme and Beck 1996; Brockwell 2006a, b; Brockwell et al. 2017; Coutts 1976, 1977, 1979; Jones 2016; Jones et al. 2017; Jones et al. 2022; Littleton et al. 2013; Martin 2006; Klaver 1998; Pardoe 2003; Pardoe and Hutton 2020; Westell and Wood 2014; Williams 1988).

Time series analyses of Australian ^{14}C dates, based on large Australian datasets, has been used by Williams et al. (2015a, b) to model population growth trajectories of Aboriginal groups in Australia[3]. They suggested that the spread of innovative ideas through regional Aboriginal populations supported growth trajectories established during the mid Holocene

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[2] All previously published radiocarbon dates have been recalibrated with OxCal (version 4.4) (Bronk Ramsey 2009), using the SHcal20 (Hogg et al. 2020) and marine 20 curves where appropriate (Reimer et al. 2020).

[3] I acknowledge critiques about the use of summed probability distributions of radiocarbon ages as a proxy for human activity and population growth (Carleton and Groucutt 2021; Surovell and Brantingham 2007; Ward and Larcombe 2020). However, it serves as a useful basis for comparison with evidence from studies as reported here on earth mounds at Calperum. As Williams et al. (2015b:12) indicated: '…we highlight the limitations of the analysis, including the complexity of radiocarbon data as a proxy, finite data in some time slices, automated processes, and disregard for local environmental situations, but our intention is to produce a first-order framework for researchers to test'.

Climate Optimum (MHCO) (c. 7000 cal BP), and were possibly due to the onset of adverse weather patterns and stress on traditional food procurement systems, from about 5000 cal BP. Such innovations potentially represented a transition to new intensive forms of food production, restricted home ranges and consequent changes in socio-economic and cultural organisation.

Prior studies of Australian Aboriginal earth mounds have focussed on spatial distribution, morphology, chronology, function and seasonality and have attempted to address research questions about landscape use, economic intensification, the economic role of women in Aboriginal society and cultural expression (Balme and Beck 1996; Brockwell 2006a; Coutts et al. 1976, 1979; Jones 2016: Jones et al. 2017; Klaver 1998; Martin 2006; Ó Foghlú 2016; Ó Foghlú 2021; Ross 2019a, b; Williams 1988). Data obtained from previous research on earth mounds has included spatial and contents analysis and geophysical techniques (including magnetic susceptibility, ground penetrating radar and gradiometric analysis) (Balme and Beck 1996; Brockwell 2006a; Coutts et al. 1976, 1979; Jones 2016: Jones et al. 2017; Klaver 1998; Martin 2006; Ó Foghlú 2016; Ó Foghlú 2021; Ross 2019a, b; Williams 1988).

This project seeks to extend this knowledge through a research program which includes the analysis of the contents and sediments collected from new excavations conducted at Calperum, a program of ^{14}C dating and via comparisons with data from previous archaeological and climate research. This research uses a number of techniques which have not previously been used in earth mound studies, in order to explore potential relationships between innovation, procurement strategies, social organisation, resource availability, diet choice and the impact of climate variability on Aboriginal peoples at Calperum from the mid Holocene.

1.2 Research design

This project tests the hypothesis that Aboriginal earth mounds located on some floodplains in northern and south-eastern Australia are representative of a broadening of diets within some Australian Aboriginal populations from about 5000 cal BP. The significant association of earth mounds with wetland environments within these regions is a potential indicator of a procurement strategy deployed to deal with novel seasonal abundance delivered by climatic and geomorphic factors, albeit with local variations in species targeted. This potentially included cyclical pulses in both animal and plant resources which induced technical innovation and the development of new management practices and social organisation in order to deal with new and evolving challenges and opportunities (see Martin [2006] for a detailed overview of heat retainer technology and the economic role of women in this context). The development of earth mounds through the intensive use of earth ovens and the subsequent creation of enduring mounded features in specific localities is potentially indicative of a key innovation within some floodplain economic systems. This was the re-purposing, or at least a change in logistic scale, of a traditional technology (ground oven cookery) in response to environmental, and/or demographic pressures arising from the mid Holocene (Jones et al. 2022; Martin 2006; Pardoe 1995, 2003).

The broadening of diets is argued to be a response to environmental challenges and associated demographic and social factors which emerged in Australia in the mid Holocene (see Edwards and O'Connell 1995; Williams et al. 2015b). Potentially, this involved the introduction of innovative management and processing techniques which allowed the efficient utilisation of seasonal resource abundance, including some previously marginal foods. This research focuses on the intensive use of a common technology (heat retainer earth ovens) to sample economic and environmental trajectories which provide insights into the regional nuances of a procurement strategy which was adopted by spatially separated populations in a similar timeframe.

1.3 Research question

How can the archaeology of Aboriginal earth mounds contribute to debates concerning Aboriginal socio-economic practices in wetland environments of the Riverland region and in the Murray Darling Basin (MDB) more widely, and how does this earth mound archaeology relate to the purported introduction of broad spectrum diets (BSD) in Australia during the mid to late Holocene?

1.4 Research aims

1. To review the available literature on Australian oven mounds and associated resource procurement strategies to define the ecological precincts and local situational contexts where Australian earth oven mounds were established.

2. To investigate the composition (macro and micro) of earth mounds located on the Calperum floodplain including faunal and botanical remains, artefacts, sediments and trends over time.
3. To investigate the chronological context of earth mounds on the Calperum floodplain and to establish their relationship to published chronological, environmental and climatic data for the wider MDB;
4. To consider and comment on the primary theoretical frameworks relevant to the analysis and reporting of this work in order to explore environmental and socio-economic factors relating to the creation of earth mounds; and
5. To consider whether the data and analysis derived from this project supports the purported emergence of BSD in Australia.

1.5 Research significance

This thesis contributes to a growing body of work centred on the Riverland region of South Australia which commenced in 2014 (Burke et al. 2016; Dardengo 2018; Dardengo et al. 2019; Incerti 2017; Jones 2016: Jones et al. 2017; Jones et al. 2022; Munt 2022; Roberts et al. 2017; Roberts et al. 2018; Roberts et al. 2020a, b; Roberts et al. 2021a, b; Roberts et al. 2022; Ross 2016; Ross et al. 2019; Thredgold 2017; Thredgold et al. 2017; Westell et al. 2020; Westell 2022). Prior to this time archaeological investigation in this region was largely confined to commercial heritage contracts associated with corporate and government entities, and is consequently unpublished. Ethno-historical accounts provided evidence of Aboriginal socio-economic practices for the broader region at the time of the European invasion and settlement in the MDB (for example see Berndt and Berndt 1974; Beveridge 1865,1869, 1883, 1889; Eyre 1845; Kirby 1895; Mitchell 1838; Sturt 1849). Such knowledge is, of course, representative of prevailing European values and perspectives at the time of observation and recording. The conduct of this research, in collaboration with the Traditional Owners (represented by the River Murray and Mallee Aboriginal Corporation [RMMAC]), has provided a focus on the ancestral achievements of Aboriginal people in the Riverland region.

Previous research on Aboriginal earth mounds has addressed a range of themes including individual and local aspects of mound morphology, spatial relationships, geophysical investigations and dating to establish local chronologies (Balme and Beck 1996; Berryman and Frankel 1984; Brockwell 2001b:1–10, 2006:47, 2009; Brockwell et al. 2017; Coutts et al 1976, 1979; Frankel 1991; Godfrey et al. 1996 Jones 2016: Jones et al. 2017; Klaver 1998; Martin 2006; Ó Foglú 2016; Pardoe 2003; Pardoe and Hutton 2020; Ross 2016; Ross et al. 2019; Sullivan 1980; Sullivan and Buchan 1980; Westell and Wood 2014; Williams 1988). The review of this research indicates mounds emerged around 5000 cal BP almost simultaneously in both northern and south-eastern Australia (Brockwell 2006a; Martin 2006; Woodroofe et al. 1988). In seminal research Martin (2006:295–297) provided the earliest evidence for the establishment of mounds within the MDB and linked the establishment and operation of earth mounds to the intensive management, harvesting and cooking of carbohydrate rich rhizomes and corms (such as *Typha* and *Bolboschoenus* spp.) associated with highly productive and permanent wetlands.

The Australian archaeological record of the period since the mid Holocene climate optimum (MHCO) at around 7000 cal BP suggests that this period included a relatively high trajectory of population growth and socio-economic intensification in Australian Aboriginal societies which has stimulated a generalised debate over the key processes and influences which applied at this time (Beaton 1983, 1985; Bowdler 1981; Hiscock 2008:253; Lourandos 1983, 1985, 1997; Lourandos and Ross 1994:54–55; McNiven et al. 2006:9; Ross 1985; Ross et al. 1992; Ulm 2006:256; Williams 1988; Williams 2015a, b). Martin (2006:308–312) concluded that the appearance of earth mounds in the archaeological record was consistent with a late Holocene socio-economic intensification. However, since this work was completed there has been little attempt to further investigate the relationship of earth mounds to changes in socio-economic practices and climate/environmental factors in Australian floodplain environments from the mid Holocene. This is a gap which this research aims to address through a considered investigation of a diverse sample of earth mounds on the Calperum floodplain.

1.6 Summary

Australian earth mounds have a widespread distribution within riverine and wetland environments in northern and south-eastern Australia (Balme and Beck 1996; Berryman and Frankel 1984; Brockwell 2006a; Brockwell et al. 2017; Coutts et al 1976, 1979; Frankel 1991; Godfrey et al. 1996; Johnson 2004; Jones 2016; Jones et al. 2017, 2022; Klaver 1998; Lane 1980; Martin 2006; Ó Foghlú et al. 2016; Ó Foghlú 2017; Sullivan 1980; Westell and Wood

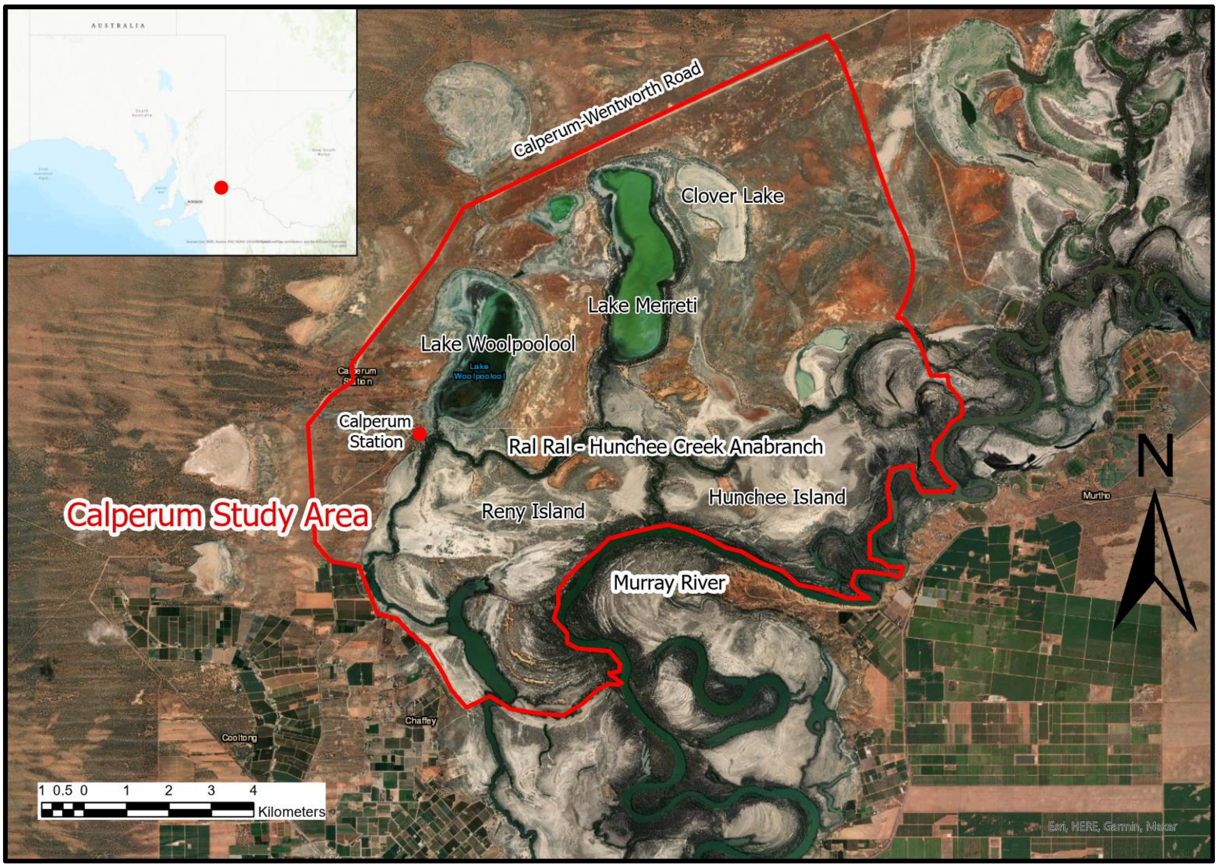


Figure 1.1: The Calperum study area.

2014; Williams 1988). The research detailed here extends on previous research (Jones 2016; Jones et al. 2017) that comprised a surface survey and analysis of 27 oven mounds located within the Calperum floodplain, near Renmark (Figure 1.1). The diversity of earth mound landscape settings within the Calperum floodplain provided an opportunity to obtain a sample of radiocarbon ages for comparison with previous research. This new study is centred on an analysis of mound contents and sediments and the establishment of a radiocarbon age chronology for mounds at Calperum, in order to provide new data for the evaluation of past socio-economic-cultural practices associated with the long-term use of earth ovens in specific localities.

1.7 Thesis outline

This introduction and a further eight chapters form the structure of this thesis. Chapter Two provides an overview of the relevant research on Australian earth mounds and the socio-economic activities associated with them. It includes a review of the purpose, chronology, morphological and functional characteristics by region; as well as an examination of the Aboriginal cultural and socio-economic significance attached to them.

Chapter Three synthesises the wider chronological, spatial and socio-economic framework which is the basis for this research. The chapter also includes a brief review of the relevant archaeology, environmental history and ethno-history of landscapes which contain earth mounds in Australia. This forms the basis of the analysis and interpretation of data, and consequently, the interplay of local socio-economic practices and environmental influences at Calperum.

The relevant theoretical frameworks which have been previously associated with the global study of ‘hunter-gatherer’ economic systems are examined in Chapter Four, which will inform the analyses and discussion of the results outlined in later chapters.

Chapter Five follows the review of explanatory theoretical models in Chapter Four by further exploring the archaeological significance of the Australian riverine floodplain landscapes which are considered in this study.

The methods considered and employed for the research conducted on the excavated materials of the six earth mounds selected for this investigation are described in Chapter Six, including a rationale for their use in each case. The methods included aerial and pedestrian survey and recording, contents analysis (artefacts, charcoal, heat retainer, plant microfossils and faunal remains), sediment characteristics (particle size, loss on ignition and magnetic susceptibility), radiocarbon dating and elemental trend analysis using portable x-ray fluorescence equipment (pXRF) as well as inductively coupled plasma mass spectroscopy (ICP-MS).

Results of the analyses outlined in Chapter Six are provided in Chapter Seven. Data is summarised in graphic form and explanatory information provided where appropriate.
The results outlined in Chapter Seven are discussed and interpretations advanced in Chapter Eight which includes an intersite comparison of contents, sediment particle size profiles, magnetic susceptibility, plant microfossil data, radiocarbon dating and elemental profiles. A consideration is made of previous interpretative models relating to socio-economic intensification, environmental influences and the potential significance of technical and social innovation in the reorganisation of landscape use and resource procurement strategies by Aboriginal people at Calperum from about 4000 cal BP. Thereafter, the

research question and aims are considered in view of the evidence produced from this study.

Conclusions are drawn in Chapter Nine, outlining the contribution of the evidence uncovered by this research, the advancement of new knowledge and an understanding of the manner in which Aboriginal groups in floodplain environments in the Riverland region managed change. Technical and socio-economic innovation is suggested to be a key element in this process through the addition of a food production system to traditional resource procurement strategies. This was potentially a response to an uncertain environment and seasonal variability in resource availability and was achieved through the large-scale exploitation of marginal and previously under-utilised plant foods.

Chapter Two: Australian Aboriginal Earth Mounds

2.1 Introduction

This chapter provides an overview of prior research about Australian earth mounds and the cultural, social and economic activities interpreted to have been associated with them. It also includes a review of their morphology, chronology and other characteristics by region that provides a contextual framework for the synthesis that is further developed in Chapter three.

2.2 Background

Aboriginal earth mounds are significant archaeological sites located in the floodplain regions of some river systems located in coastal northern Australia, the northern Adelaide Plains, western Victoria and the MDB (see Figure 2.1) (Balme and Beck 1996; Berryman and Frankel 1984; Brockwell 2001b:1–10, 2006:47, 2009; Brockwell et al. 2017; Coutts et al 1976, 1979; Frankel 1991; Godfrey et al. 1996; Jones 2016; Jones et al. 2017; Jones et al 2022; Klaver 1998; Lane 1980; Martin 2006; 'O Foghl´u et al. 2016; 'O Foghl'u 2017; Shiner and Morrison 2009; Westell and Wood 2014; Williams 1988; Woodroofe et al. 1988). Earth mounds of the MDB and northern Australia typically contain abundant heat retainer material (depending on region, this can be predominantly burnt clay or termite mound material although stone may also be present), and are probably created from the repeated use of earth ovens in the same location, for the cooking of a seasonal abundance of food resources (Jones et al. 2022; Westell and Wood 2014). Mounds reported by Williams (1988) and Coutts (1976) in western Victoria have been interpreted as multi-functional occupation sites with higher numbers of artefacts and faunal remains than those in other regions. Based on the archaeological evidence from surveys and excavation, earth mounds in the MDB and northern Australia were probably used to provide large quantities of carbohydrate, protein, and fibre to both local groups, and regional aggregations of people (Brockwell 2006a; Brockwell et al. 2017; Jones et al. 2022; Martin 2006, 2011; Pardoe and Hutton 2020). Functionally and chronologically, earth mounds are potentially indicate the development of intensive foraging strategies of both animal and/or plant resources and plant management practices in these areas since at least the mid Holocene (Figures 2.2 and 2.3). The repurposing of heat

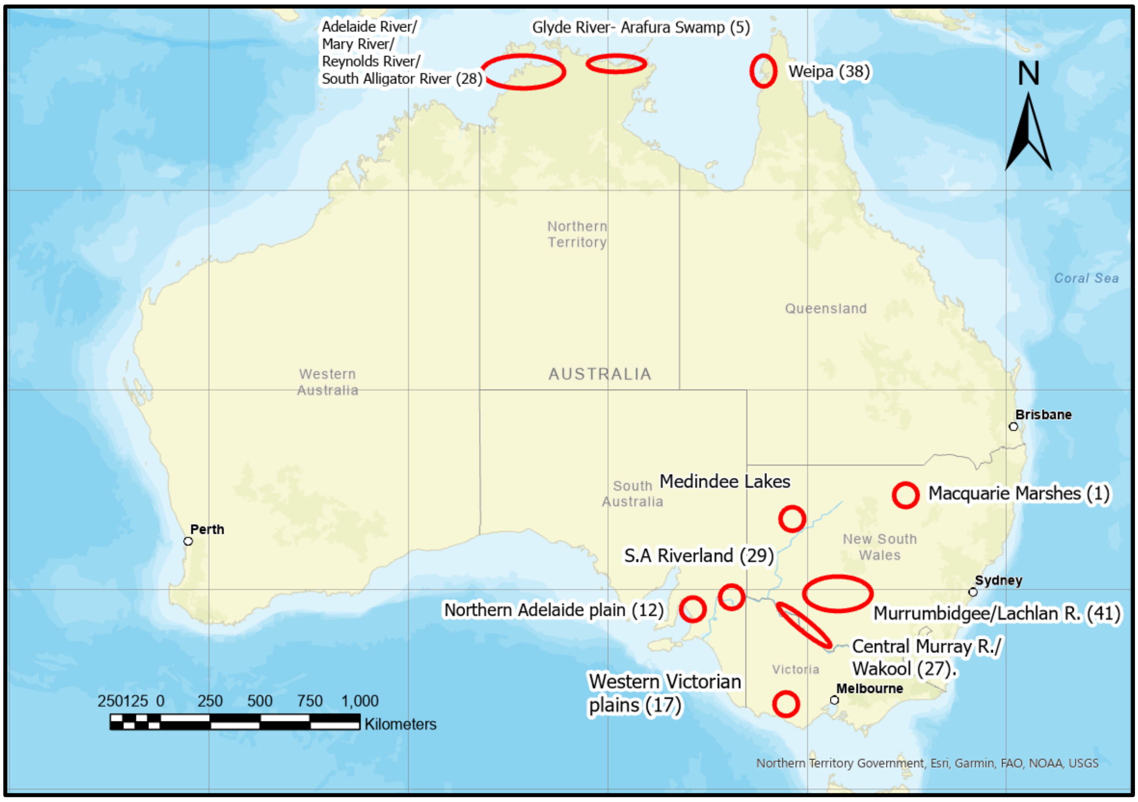


Figure 2.1: The major locations of earth mounds in northern and south-eastern Australia showing the number of previously published ^{14}C dates and those obtained in this study, as of 1 July 2022 (Balme and Beck 1996; Brockwell 2006a; Brockwell et al. 2017; Coutts 1996; 1997; Jones et al. 2017; Jones et al. 2022; Klaver 1988; Martin 2006, 2011; Pardoe 2003:43; Westell and Wood 2014:32).

retainer technology potentially represents an important innovation in response to environmental and demographic pressures and a broader diet in some Australian wetland regions during this period.

Martin (2006:11) described earth mounds as a:

> …cultural deposit that is mounded and circular or elliptical in outline, [with] usually dark coloured, organic rich sediment, the dark grey to black colour due to the addition of ash, charcoal, burnt animal bone or mussel shell, and other organic material possibly including animal fats and plant waxes. Weathering may bleach the deposit to medium to pale grey or grey-brown [and, containing] varying amounts of heat retainers of stone or clay material that have been heated in a fire and then enclosed in an oven to act as a heating element for prolonged cooking.

Earth mound studies within Australia have been conducted for both academic and heritage management purposes and have included local and regional studies of functionality, spatial distribution, morphology, chronology and seasonality (Brockwell 2006a; Coutts et al. 1976:42–43, 1979; Jones 2016; Jones et al. 2017; Klaver 1998; Martin 2006, 2011; Pardoe and Hutton 2020; Westell and Wood 2014) (Figure 2.2). These data have informed a wider

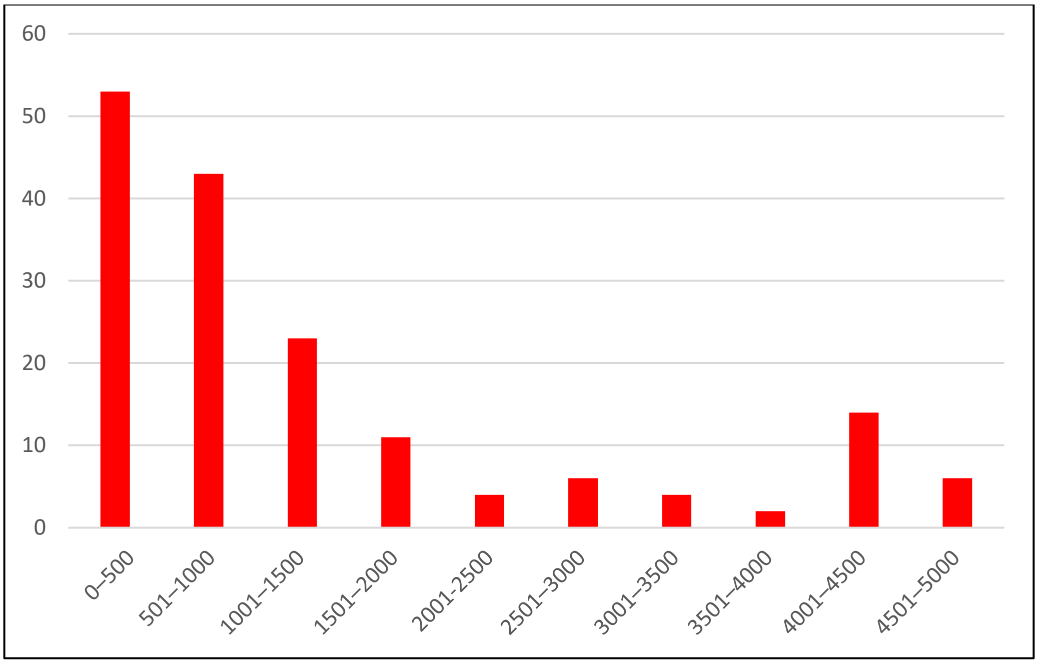


Figure 2.2: ^{14}C age profile of previously published Australian earth mounds (derived from Balme and Beck 1996; Brockwell 2001b, 2005, 2006 a, b, 2009; Brockwell and Ackermann, 2007; Brockwell et al. 2009, 2017; Coutts et al. 1977; Godfrey et al. 1996; Johnson 2004; Klaver 1998; Martin 2006; Berryman and Frankel 1984; Westell and Wood 2014; see also the AustArch ^{14}C dataset available at <Https://archaeologydataservice.ac.uk/archives/view/austarch_na_2014/index.cfm)>.

debate about past lifeways and function, cultural expression, socio-economic intensification, social organisation and relationships within long-term trajectories of climate change.

The seasonal use of earth ovens in the same location over extended periods for food preparation and plant fibre processing has been suggested to be the impetus for the origin of mounds within the MDB (Jones 2016; Jones et al. 2017; Jones et al. 2022; Klaver 1998; Martin 2006; Westell and Wood 2014). In northern Australia, mounds have been linked to a wide variety of animal and plant food resources (Brockwell 2001b, 2005, 2006a, b, 2009; Brockwell and Ackermann 2007; Brockwell et al. 2009, 2017). Other factors involved in their formation (though not in all regions) include the provision of living spaces (particularly during flooding), as cultural landmarks as a result of the accumulation of general lifestyle debris including mussel shells, other faunal remains, decayed residential structures and occasional burials (Coutts et al. 1976, 1979; Brockwell 2001b, 2009: Westell and Wood 2014:30–65; Williams 1988). Ethno-historical accounts indicate that earth mounds were used for extended periods on a seasonal basis and consequently represent an enduring asset to the groups that created them (Berndt and Berndt 1974; Beveridge 1865, 1869, 1883, 1889; Eyre 1845; Kirby 1895; McConnel 1953; Mitchell 1838; Thomson 1939a:221; Morrison et al. 2022; Peterson 1973; Sutton 1994).

Earth mounds were possibly operated by clan or family groups on the Murray River (Eyre 1845 [2]:291). Consequently, earth mounds may have had a formal relationship to defined groups, determined by cultural and socio-economic criteria, where a seasonal supply of critical nutritional resources was provided by female members of the group (Beveridge 1889:32–34; Kenyon 1912:102; Martin 2006; Mitchell 1839 [2]:53, 60, 80–81, 134; see also Hiatt [1974] for a discussion on the role of women in Aboriginal subsistence systems).

There are many archaeological contexts around the world that have structures that share similarities to Australian earth mounds, which may be termed 'burnt mounds' or 'burnt rock middens'. These are found extensively in Europe (Anthony et al. 2001; Beamish and Ripper 2000; Buckley 1991; Gillespie 1991) and North America (Black et al 1997; Hawley 2003; Saunders and Allen 1994; Saunders et al. 1997; Smith and McNees 1999; Sullivan et al. 2001). European and North American examples date from approximately 30,000 and 10,000 years ago respectively (Black and Thoms 2014:204–205). Black and Thoms (2014) described these structures, explaining the innovation which differentiates them from hearths. Essentially this involves the application of heat and moisture in a low oxygen environment which cooks and conserves fuel at the same time (Black and Thoms 2014:204–206). Calories can be accessed from otherwise unsuitable foods by breaking down plant based toxins and complex carbohydrates which are otherwise unsafe or unable to be digested in the human gut (Ferrier 2015:104; Ferrier and Cosgrove 2012:106; Martin 2006). In his study of geophagy and Aboriginal plant food processing technologies, Rowland (2002:50–65) suggested that a detailed knowledge of food toxicity and methods of elimination had a very long history in Australia. He noted the consumption of clay and charcoal by Aboriginal peoples for the treatment of various ailments and the detoxification of various poisonous foods, as well as the application of heat in earth oven cookery for the break-down of 'purgative and emetic properties', including those in *Typha* spp. rhizomes (Rowland 2002:56–57). Brockwell (2001b:1–23) noted that, from an archaeological perspective, the study of the chronologies, contents, morphology and spatial relationship of earth mounds to economic resources provides a potential window on changes in floodplain subsistence strategies, social and cultural systems and relationships to variable environmental conditions.

Research into Australian earth mounds has been used in interpretive models developed to explain a purported intensification in Aboriginal societies in the latter half of the Holocene (e. g., Hiscock 1988:188–189; Lourandos 1980, 1983, 1997; Williams 1988). Such models were formulated from archaeological evidence which indicated an increase in site numbers and changes in behaviour, social organisation, and socio-economic activity during this period (Lourandos 1980, 1983, 1997). Contextually, earth mounds potentially provide insights into the socio-economic strategies of a significant sample of widely separated Aboriginal groups living in floodplain landscapes during this period. Such insights may include the broadening of diets from this time, changes in plant procurement and cooking systems, cultural expression and style through landscape modification as well as a reorganisation of intra-group socio-economic resources (Brockwell 2006a; Jones et al. 2022; Martin 2006).

2.3 Earth mound typology and function

Aboriginal use of fire has resulted in a spectrum of evidence demonstrated in the environmental and archaeological records at both macro and micro scales. Such evidence ranges from charcoal residues indicating the modification of vegetation within landscapes as a form of deliberate ecological niche construction, termed firestick farming by Rhys Jones (1969) (see also Bliege Bird et al. 2008) to the residues of various fire related features. These latter features include hearths, ground ovens and earth (oven) mounds which have been demonstrated at a multitude of individual sites across the continent (see Pardoe [1993] for an account of the presence of fire related features in western New South Wales). A range of physical features associated with the domestic use of fire for cooking and heat are demonstrated in the archaeological record. These include hearths, remnant earth ovens, excavation pits, discrete areas of ashy soil and/or heat retainer sediments; and mounded earth structures formed variously from the accumulation of lifestyle debris, ash, charcoal and heat retainer material. Burnt clay, termite mound and/or stone heat retainer material in an ashy soil matrix together with freshwater mussel shell[4], animal bone and occasional burials are characteristics of earth mounds as defined within Aboriginal Australian archaeological contexts. They exhibit significant intra and inter regional diversity in morphology and chronology (Brockwell 2001b, 2006a, 2009; Jones et al. 2017; Jones et al. 2022; Klaver 1998:122–135; Martin 2006; Pardoe 2003; Westell and Wood 2014). Such diversity renders simple definitions difficult to apply (as for instance, those of Coutts et al. [1976, 1979] who favoured limited classifications) when applied to the range of regional features which contain these materials. Diversity at both the local and regional level suggests regionally distinct and complex taphonomic processes influencing site development over time.

Earth mounds are typically located in floodplain environments in close association with highly productive seasonal wetland resources such as swamps, anabranch creeks, break-out creeks, billabongs and lakes (Brockwell 2001b, 2006a, 2009; Jones et al. 2017, 2022; Klaver 1998; Martin 2006; Pardoe 2003; Pardoe and Hutton 2020; Westell and Wood 2014; Williams 1988). The presence of either burnt stone, clay and termite mound nodules as heat retainers are a strong indicator that processes such as cooking, detoxification and fibre processing occurred within such sites. This is supported by the frequent association of mussel shell, charcoal, heat retainer material and other faunal remains, although these are not necessarily found together, and in varying ratios when present. By virtue of the environments in which they occur, earth mounds are subject to periodic flooding regimes, thus their continued vertical development potentially constitutes an adaptive response to seasonal inundation in some cases. For instance, Coutts et al. (1979:82) concluded that cooking mounds on the Murray River floodplain near Swan Hill in north-western Victoria, were sometimes developed into occupation spaces. In the Adelaide River region of Arnhem Land, in the Northern Territory, they are located on natural rises at floodplain margins and often associated with ephemeral lagoons and the intersection of resource zones (Brockwell 2001b:200, 2009; Guse 2005:89–90).

[4] Freshwater mussel shell is found in archaeological contexts within the MDB and are typically from two species *Velesunio ambiguous* and *Alathyria jacksonii*, from lacustrine and riverine environments respectively (Garvey 2013:121; Walker 1981:1241; Walker et al. 2001; Walker 2017). Brockwell (2001b) lists a different species (*V. angasi*) for freshwater environments in Arnhem Land.

Klaver (1998:122–135) provided a classification system for earth mounds and associated features from her research in the Murrumbidgee Irrigation Area, which is useful for the consideration of typological variability in the Australian context (Table 2.1). Table 2.2 identifies key regional earth mound datasets for the major Australian mound precincts. Klaver (1998:135) used the term 'earth mound' as a generic label for features at the first level of analysis, acknowledging the difficulty of classifying the eroded remains of mounds, which may present as a lag deposit of heat retainer nodules on an underlying exposed surface. I have adopted this classification system and terminology as the basis of analysis for this review.

2.4 Cultural landscapes

Further to the various functions outlined previously, earth mounds have also been assigned a symbolic role within cultural landscapes. From this perspective, earth mounds potentially functioned as indicators of ownership and delineators of group boundaries (Brockwell 2001b:201, 2006a:54, 2009; Frankel 1991:82; Martin 2006; Westell and Wood 2014:57). The regular spacing of mounds within Murray Valley floodplains, along water courses and around billabongs, are cited in support of this hypothesis (Frankel 1991; Jones 2016; Jones et al. 2017). This also correlates to Pardoe's (1988) cultural model of exclusion based on the analysis of Aboriginal cemeteries as symbols of territorial ownership within the MDB.

Martin (2006:301–306) constructed a cultural and social landscape model from her research located on the Hay Plain in south-western New South Wales, an area in which the Aboriginal socio-economic system was largely oriented around earth mound construction and operation in the mid to late Holocene. She maintained that the association of Aboriginal women with the establishment and scale of operation of earth mound based production underlined the economic contributions of women and potentially an enhanced status within floodplain Aboriginal groups. Martin (2006:282–286) used archaeological and ethnographic evidence to argue that considerable social and economic power was exercised by women through the seasonal supply of important plant foods (e. g., rhizomes from *Typha* spp.) via the management, procurement, preparation and cooking of large quantities when available (see also Gott 1982, 1999). A range of relatively small to some very large earth mounds within the western Hay Plain region were the physical expression of this inferred influence. The scale of this subsistence system indicated a high level of co-operation and coordination amongst generations of individuals and suggested that women exercised leadership through the application of innovations to resource management and procurement, which induced changes in internal group social relationships (Martin 2006:286–287).

Martin's (2006) model expanded on utilitarian models of earth mound use and is consistent with social models proposed for Australian populations from the mid Holocene which posit changes in territorial, social and hierarchical structures (see Lourandos 1980, 1983, 1997). Martin (2006:308–312) argued for reduced territories and social change in the Hay Plain study area from the mid Holocene, noting the establishment and operation of earth mounds from about 5000 cal BP until the European invasion. The application of wide scale and intensive application of heat retainer cooking technology to the processing of wetland plants emerged as a key component of local subsistence strategies from this time (Martin 2006:308–312).

2.5 Domiculture and resource management

Domiculture is defined by Hynes and Chase (1982:38) as:

> …hearth-based parcels of knowledge, strategies and actions applied to each 'domus', where 'domus' refers to a …specific area where selective environmental knowledge and resource strategies are applied at a specific time.

Balme and Beck (1996:45) proposed domiculture as a potential process relevant to earth mounds within the MDB, stressing the lack (at the time) of a generally accepted function for which they were constructed. They argued that the evidence of burning demonstrated by the presence of charcoal, baked clay and dark ashy sediments, within mounds, indicated that domiculture was the only common process consistent with the evidence (Balme and Beck 1996:45). In support of their hypothesis, Balme and Beck (1996:47) linked regionally apparent discontinuities in mound use to an intermittent strategy of deliberate vegetative propagation of tuberous plants. In their view, this would have occurred as a response to low resource productivity due to seasonal variations in natural growth, thereby increasing the availability of resources in support of extended sedentary periods (Balme and Beck 1996:47).

Cribb (1996) and Cribb et al. (1988) suggested that earth and shell mounds in western Cape York were associated with domiculture and implied resource ownership by individual groups. The vegetative propagation of yams, by replanting portions of tubers to allow regrowth, is an often cited activity in this context (Hynes and Chase 1982:40).

Downie et al. (2011) researched earth mounds in the MDB, finding that the soils developed in these sites could be classified as cumulic anthroposols (*terra preta*), with traits similar to soil aggregates in the Amazon Basin. This soil differs from surrounding soils by higher levels of Carbon (C), exchangeable Calcium (Ca), higher pH, greater water holding capacity and consequently provides a greater ability to support plant growth as indicated by examples of the excavation and use of such soils in modern gardens (Downie 2011:142–143). Downie et al. (2011:142) indicated that in the Australian context *terra preta Australis* sites are geographically restricted and generally smaller in comparison to those in the Amazon associated with *terra preta de Indio* soils.

Eyre (1845:269), Grey (1841:292) and Mitchell (1839:60) recorded instances of the management and exploitation of *Typha* spp. by Aboriginal peoples during exploratory journeys in the middle of the 19th Century. Natural stocks of *Typha* spp. occurring in the floodplain environments of the MDB were managed to increase production of carbohydrate-rich rhizomes through 'firing, gathering and digging', which Gott (1982:65) considered to be a form of 'natural cultivation'. *Typha* is moderately salt tolerant and thrives in floodplain environments subject to variable water availability which make this plant valuable as a source of carbohydrate and fibre in such environments (Beare and Zedler 1987; Hocking 1981; McMillan 1959; Whigham et al. 1989; Zedler et al. 1990). The exploitation of *Typha* is considered to be domiculture on the basis of the deliberate management of plants which enhanced the production of rhizomes and the yield of carbohydrate (Gott 1982, 1999; Martin 2006:278–282).

The prolific presence of earth mounds within floodplain environments, developed through the repeated use of earth oven technology in specific locations, indicates the availability of a seasonally abundant plant based food resource. This suggests the adoption by local Aboriginal peoples of an intensive procurement strategy potentially including resource management strategies such as firing to maximise growth and productivity in order to access the nutrition available.

Table 2.1: Earth feature characteristics, derived from Klaver (1998), see also Jones (2016) and Jones et al. (2017).

Site Component	Sediment particle size	Features	Description	Site size	Activity	Comment	Source
Ashy sediment accumulation	Fine grain	Occupation floors/ General camping.	Mixed deposits of soil and ash.	Large/ Irregular.	Campsite.	Mixed surface. May be disturbed oven mound site.	Ethnography
		Open hearth campfire.	Charcoal/soil and ash.	Less than 1 metre.	Campsite.	Continued use may evolve into mounded structure – occupation mound.	Archaeology
Excavated pit	N/A	Small oven pit.	Burnt clay present.	Less than 1 metre.	General camping.	Other artefacts and material present.	Ethnography
		Large oven pit.	Depression.	Up to several metres in diameter.	Processing large quantities of materials or food.	Association with plant resource zone.	Ethnography
Fired clay heat retainer	Range from 0.5 cm to 15 cm	Small pit ovens	Rake-out piles	I metre diameter	Cooking.		Archaeology
		Multiple pit ovens.		N/A	Cooking.		Archaeology
		Above ground oven structures.	Aggregations without in-ground pits.	Variable.	Reuse for cooking	Grouped aggregations over large surface. Incipient mounds.	Archaeology
		Oven mound.	Discrete, mounded, many burnt clay lumps.	Variable.	Repetitive use of small pit ovens.	Mussel shell and artefacts. Compact or soft.	Ethnography
		Occupation earth mound.	Discrete and mounded few burnt clay lumps.	Variable.	Camping.	Few artefacts and other materials.	Ethnography
		Pit ovens within midden deposits	Matrix dominated by shell fragments.		Cooking within midden deposits.		Archaeology
		Utilised natural mounds.	Natural rises, animal activity, tree fires.		Natural processes.		Archaeology

Table 2.2: Key regional datasets by mound precinct. Note that in many studies listed, earth mounds were only one site type in a wider investigation.

Earth mound precinct	Study area	Citation
South Australia	Northern Adelaide Plains	Westell and Wood (2014); Draper (1992); Littleton et al. (2013)
	SA Riverland	Jones et al. (2017); Westell and Wood (2014)
North central Victoria	Swan Hill	Coutts et al. (1979)
	Wakool/Barmah	Buchan (1980); Berryman and Frankel (1984); Frankel (1991); Pardoe and Hutton (2020); Simmons (1980)
Macquarie Marsh N.S.W.	Macquarie River	Balme and Beck (1996)
Western Victoria	Hopkins River	Coutts et al. (1976)
	Caramut	Williams (1988)
Western NSW	Menindee Lakes	Pardoe (2003)
South central NSW	Hay Plain	Martin (2006)
	Murrumbidgee	Klaver (1998)
Northern Territory	Adelaide River	Brockwell (2001b, 2005, 2006a, b); Brockwell & Ackermann (2007); Schrire (1968); Smith (1981)
	Darwin Harbour	Bourke (2000)
	Mary River	Baker (1981)
	South Alligator River	Brockwell (1989); Meehan et al. 1985); Woodroffe et al. (1988)
	Reynolds River	Guse (2005); Guse and Majar (2000)
	Blyth River	Meehan (1988, 1991)
	Arafura Swamp	Peterson (1973)
	Milingimbi	Roberts (1994)
Northern Cape York	Weipa	Brockwell et al. (2017); Cribb (1986); ‘O Foghl’u (2017); ´O Foghl´u, et al. (2016); Shiner and Morrison (2009)

2.6 Regional chronologies and physical dimensions

2.6.1 Chronology

In northern Australia research conducted at the Madjedbebe rock shelter indicated a human presence around 65,000 cal BP in the Arnhem Land region (Clarkson et al. 2017). The oldest ages obtained in the MDB are associated with the Willandra and Menindee lakes at 45,000–50,000 cal BP (Weston et al. 2017). Prior to the Holocene, the morphology and low resource base of prior and ancestral river systems within the MDB implies a preference by local populations for the safer and greater resource abundance of lacustrine environments such as existed at Lake Mungo (Willandra lakes) during the Pleistocene (Bowler et al. 2003; Pardoe 1995). Until recently, the oldest published age associated with any site type, in a MDB riverine environment, was about 20,000 cal BP (Edmonds 1998), although recently an age of about 28,000 cal BP has been reported from a shell midden on the clifftop edging the Pike River floodplain (Figure 6.1a) in the Riverland region of South Australia (Westell et al. 2021). These data suggest that careful site survey and selection can assist the identification of older sites in the MDB where the complex geomorphology makes them difficult to locate.

One hundred and sixty four calibrated ^{14}C dates derived from earth mound sites in both south-eastern and northern Australia have been compiled and compared by sub-region in Figure 2.3 (see also Appendix Nine). Of these, 144 date from <3500 cal BP and 20 range between 3500 and 5000 cal BP. Thus, from current evidence, the majority of remnant earth mounds, which have been recorded and dated in Australia, are late Holocene with 78% of ages less than 2000 cal BP. Material with dates older than 3000 cal BP have been excavated from sites at Wakool and the Hay Plain, in south-western New South Wales, and at Adelaide River and Weipa in the Northern Territory and north Queensland regions respectively. However, while included in this dataset, an age of 3291–2822 cal BP (WK36516) determined on shell from EM SM81 at Weipa is potentially unreliable, as it appeared the earth mound material was a later addition to a previously established shell mound (Brockwell et al. 2017:5). An age of 12,596–12,095 (NZA-38322) obtained from the base of the Gillman mound in northern Adelaide was also excluded from this analysis as it was highly probable that it was not associated with mound formation processes as the charcoal dated was obtained from burnt clay and considered to be derived from older sediments disturbed by mixing (Littleton et al. 2013) (see Figures 2.3, 2.4 and Table 2.3).

Ages for mounds located south of the Murray River, in the north-west and northern regions of Victoria, date from 2,093–1,840 cal BP (WK-11149) obtained from a mound at Lake Boort. North of the Murray River, ages increase through the Wakool region with the oldest located near Balranald in the south-west area of the Hay Plain (5,319–4,425 cal BP, WK-4101). Further north, the ages of mounds in the Murrumbidgee River region are younger with an age range of 3481–2724 cal BP (ANU-7881) being the oldest obtained. The maximum ages recorded for mounds located in close proximity to the MDB, in the western districts of Victoria and the northern Adelaide Plains, are 2716–2090 cal BP (SUA-574) and 2281–1899 cal BP (NZA-35232) respectively (See Appendix Nine for a full list of previously published ^{14}C earth mound ages).

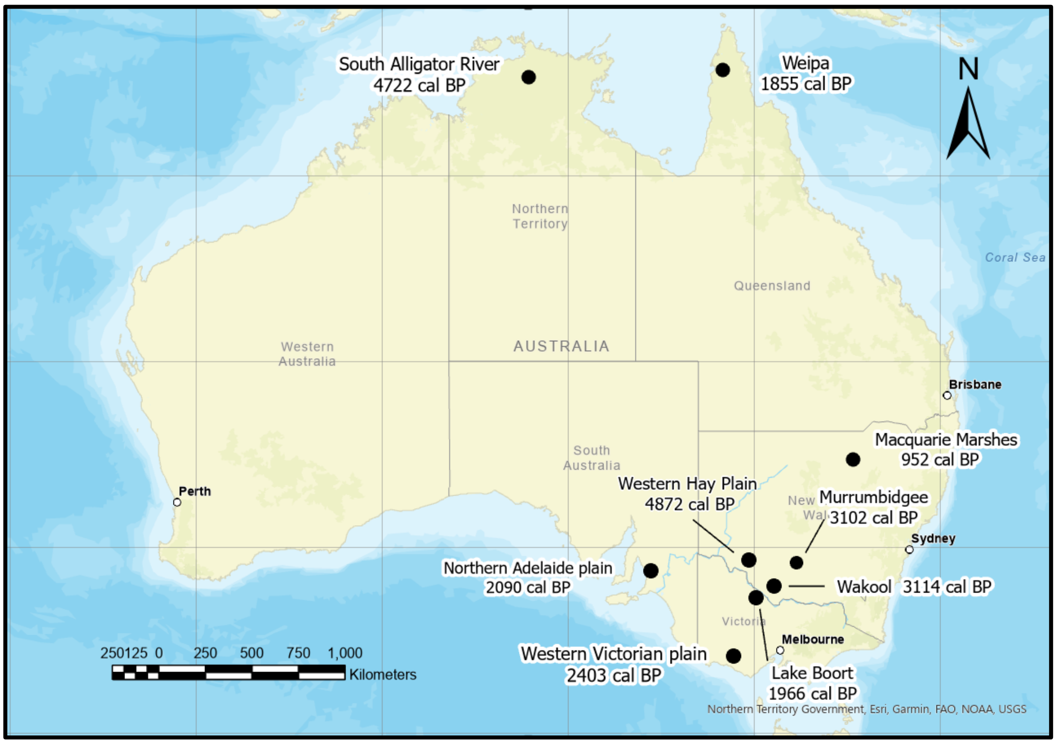


Figure 2.3: The oldest calibrated age range median for Australian earth mounds in the major mound precincts (South Australian Riverland excluded) (Balme and Beck 1996; Brockwell 2001b, 2005, 2006 a, b; Brockwell and Ackermann 2007; Brockwell et al. 2009, 2017; Coutts et al. 1977; Godfrey et al. 1996; Johnson 2004; Klaver 1998; Littleton et al. 2013; Martin 2006; Berryman and Frankel 1984; Westell and Wood 2014; Woodrooffe et al. 1988).

Table 2.3: Numbers of calibrated ^{14}C verified ages (median) by region in 500-year periods (Balme and Beck 1996; Berryman and Frankel 1984; Brockwell 2001b, 2005, 2006 a, b; Brockwell and Ackermann 2007; Brockwell et al. 2009, 2017; Coutts et al. 1977; Godfrey et al. 1996; Johnson 2004; Klaver 1998; Littleton et al. 2013; Martin 2006; Westell and Wood 2014); Woodrooffe et al.1988).

Precinct	Calibrated Radiocarbon Age BP										
	0-500	501-1000	1001-1500	1501-2000	2001-2500	2501-3000	3001-3500	3501-4000	4001-4500	4501-5000	Total
Western Vic.	4	4	5	3	1	0	0	0	0	0	**17**
Nyah	2	7	8	0	0	0	0	0	0	0	**17**
Nth. Adelaide	1	8	0	1	1	0	0	0	0	0	**11**
Lake Boort	3	2	0	1	0	0	0	0	0	0	**6**
Hay Plain	0	0	0	0	0	0	0	1	10	6	**17**
Murrumbidgee	9	10	0	0	0	4	1	0	0	0	**24**
Wakool	0	0	0	0	1	1	1	0	0	0	**3**
Goulbourn R.	2	0	0	0	0	0	0	0	0	0	**2**
M. Marsh	0	1	0	0	0	0	0	0	0	0	**1**
N. Territory	11	5	5	2	0	1	1	0	2	1	**28**
Weipa	26	4	3	3	1	0	1	0	0	0	**38**
Total	**58**	**41**	**21**	**10**	**4**	**6**	**4**	**1**	**12**	**7**	**164**

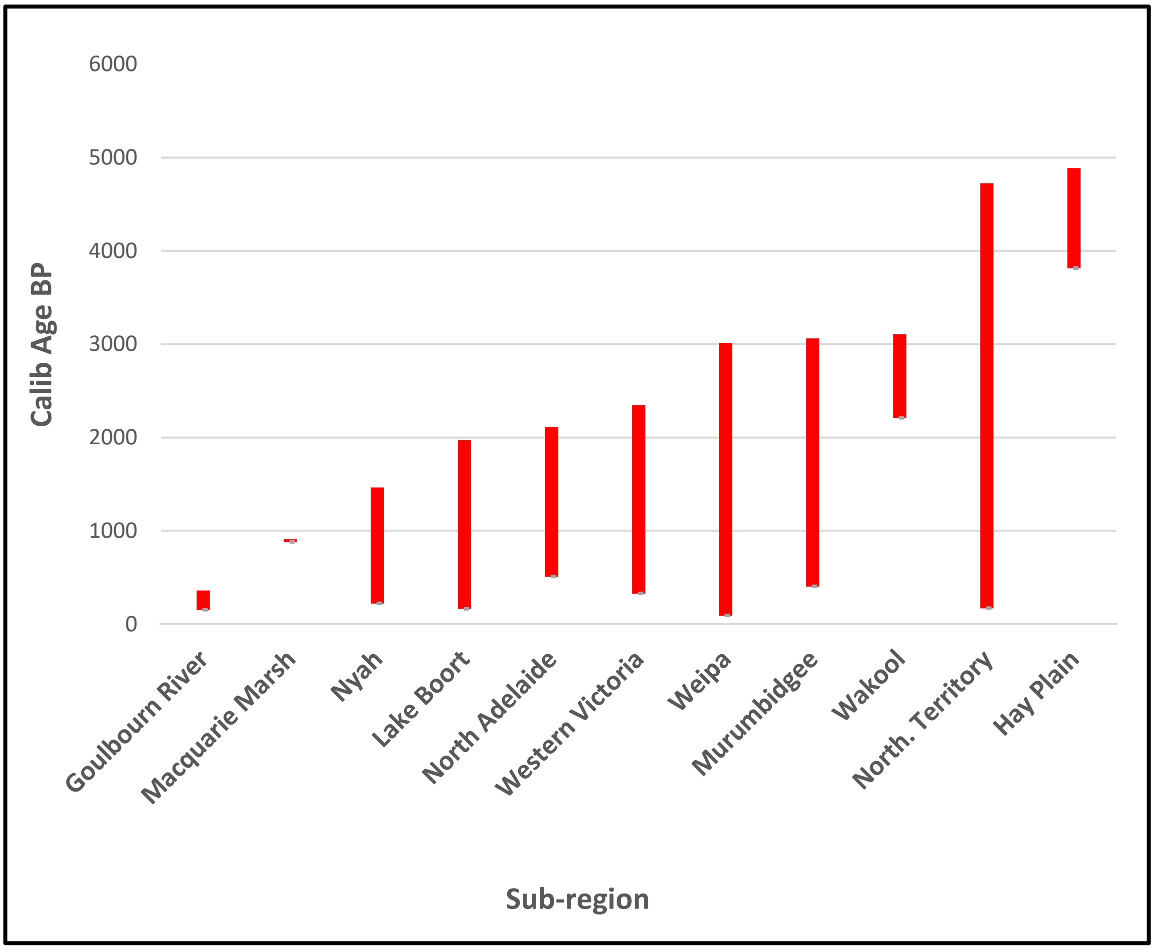


Figure 2.4: Earth mound ^{14}C calibrated age ranges by region (Balme and Beck 1996; Brockwell 2001b, 2005, 2006 a, b; Brockwell and Ackermann 2007; Brockwell et al. 2009, 2017; Coutts et al. 1977; Godfrey et al. 1996; Johnson 2004; Klaver 1998; Littleton 2013; Martin 2006; Berryman and Frankel 1984; Westell and Wood 2014).

Mounds located on seasonally active riverine floodplains in the MDB date to less than 3500 cal BP, whereas those associated with lacustrine environments near Balranald (Hay Plain) are older. The older ages of mounds in the Wakool and Hay Plain regions possibly indicate an earlier origin for this technology in this part of the MDB, however older earth mounds in other areas of the MDB may have been removed by the lateral movement of river channels and subsequent taphonomic processes. The early dates obtained in the Northern Territory and Weipa region (4,726 cal BP, ANU-3992 and 3,014 cal BP, Wk-36516 respectively) likely indicate that earth mounds in those areas were developed independently from those located in the MDB, located approximately 3,500 km to the south. However, mounds in all regions potentially developed as an adaptive response to similar environmental drivers in quite different climatic regions.

2.7 Earth mound studies by region

2.7.1 South-eastern Australia

2.7.1.1 South Australia

Westell and Wood (2014) provided a synthesis of previous research on Aboriginal earth mounds in South Australia, detailing their formation processes, distribution, typology and associated artefact assemblages. Their analysis indicated that 31 mounds had been previously recorded within the northern Adelaide plains (Figures 2.1, 2.10, 2.11). Historical evidence also indicated that mounds were previously associated with sections of the Sturt and Torrens Rivers now located within the south-central and central suburbs of the City of Adelaide (Figure 2.11) (Westell and Wood 2014:35–44). Agricultural activity and urban development since European colonisation has destroyed most of these mounds. Draper (1992) indicated there were two types of mounds present with diameters of 10–57 metres and a height range between 0.1–1.3 metres. The most numerous mounds (type 1) were at the low end of the diameter and height range above, circular in shape and contained homogeneous accumulations of burnt clay nodules and charcoal in an ashy soil matrix (Westell and Wood 2014:40). The second type was at the higher level of the dimensional range and less numerous, included burials in some instances and demonstrated a more diverse assemblage of materials which probably indicated their use as living space (Littleton

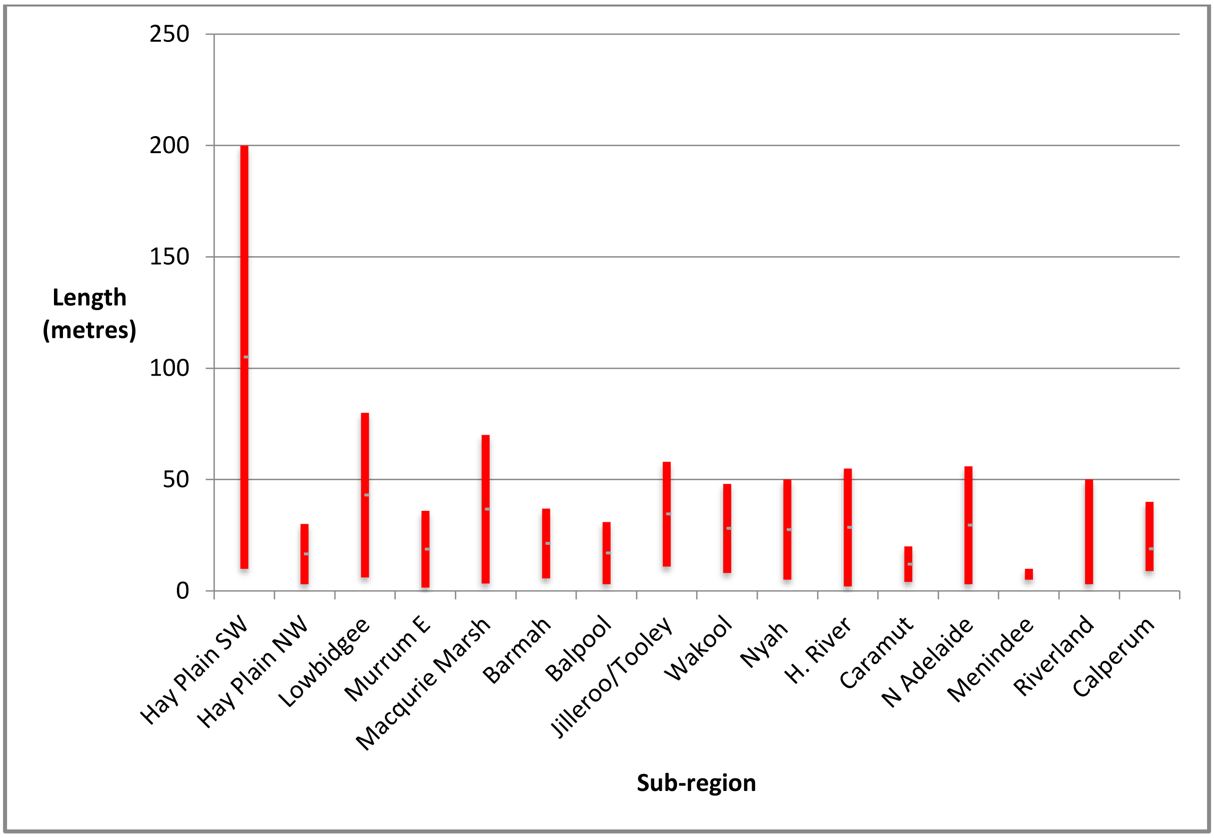


Figure 2.5: A comparison of mound length range by MDB sub-region as reported by Jones et al. (2017) (derived from Balme and Beck 1996: Berryman and Frankel 1984; Coutts et al.(1976, 1979; Jones 2016; Jones et al. 2017; Martin 2006; Simmons 1980; Westell and Wood 2014; Williams(1988).

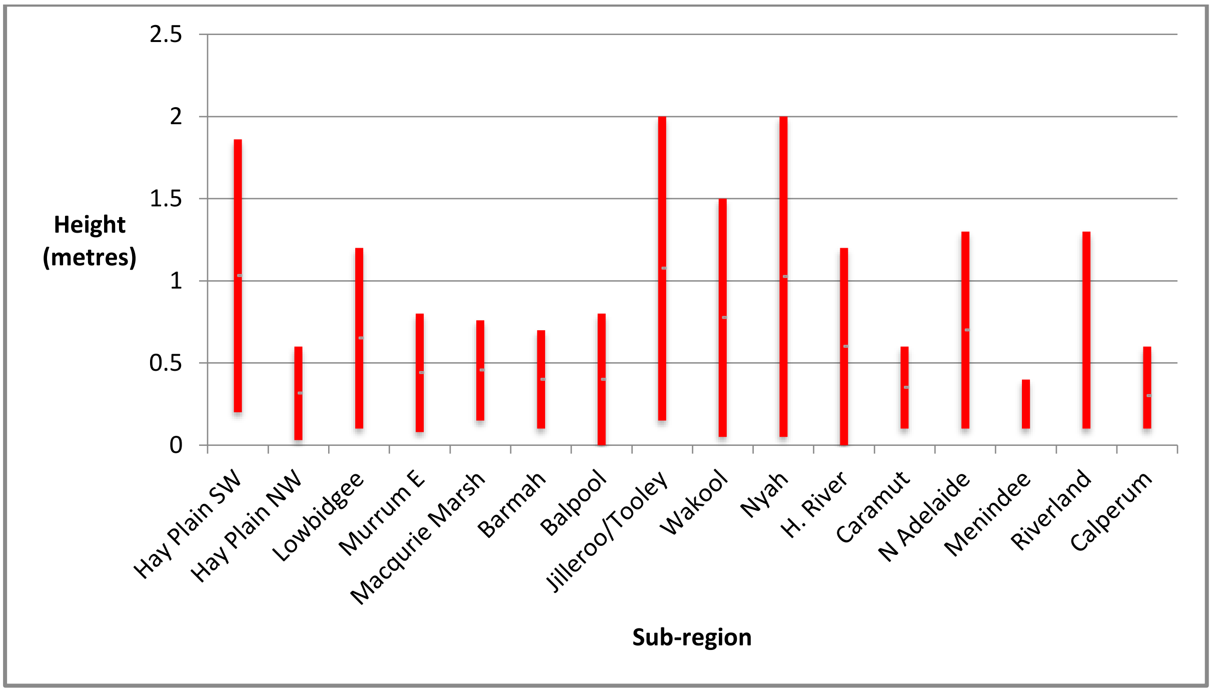


Figure 2.6: Mound height range by MDB sub-region as reported by Jones et al. (2017) (derived from Balme and Beck 1996: Berryman and Frankel 1984; Coutts et al.(1976, 1979; Jones 2016; Jones et al. 2017; Martin 2006; Simmons 1980; Westell and Wood 2014; Williams(1988).

et al. 2013; Westell and Wood 2014:41–42). See Figures 2.5 and 2.6 for dimensional details of MDB earth mounds.

Hodges (1973) excavated a mound at Gillman, in the Port Adelaide region of the north Adelaide plains (Figure 2.11), which was subsequently re-examined by Littleton et al. (2013). At the time of the later excavation, the mound was estimated to have had an original diameter of at least 24 metres with a height over three metres, this was more than double its size at the time of excavation. A top layer of 2–3 metres of calcareous sand containing dark ashy occupation debris, and a lower layer of red sand extending below the surrounding ground level, was revealed during the excavation. From their analysis Littleton et al. (2013:38, 49) concluded that the site demonstrated episodic occupation rather than casual use. This conclusion was based on the diversity and regularity demonstrated by the nature of burials found in the site (Littleton et a. 2013:49).

The results of a stable nitrogen isotope study by Owen and Pate (2014:48–51) of ancestral Aboriginal skeletal material recovered from a mound site in Salisbury (Figure 2.11), north of Adelaide, showed evidence that dietary protein was obtained from terrestrial rather than marine sources, for the individuals represented (see also Bass [2005], Buikstra and Ubelker [1994] and Furniss and Habberfield-Short [2011:21–29] cited by Owen and Pate [2014] for background to this method). This was unexpected considering previous evidence of the inclusion of seafood in the diet of other related groups and the near-coastal location of the burial site (Owen and Pate 2014:50). Following a reanalysis of both chronological and ethnographic data, Owen and Pate (2014:51) concluded that shifts to more local food sources in the late Holocene potentially indicated increased territoriality and sedentism.

Westell and Wood (2014:45) recorded 175 earth mounds along the length of the Murray River from Lake Alexandrina to the Victorian border (Figure 2.11), with the highest number recorded between the town of Loxton, in the South Australian Riverland, and the state border with Victoria and New South Wales (Figure 2.1 and 2.11) (see also Jones [2016], Jones et al. [2017] and Jones et al. [2022]). Earth mounds in this section of the Murray River are generally circular with diameters between 3–50 metres and 0.2–0.7 metres in height, containing burnt clay pellets, ash and charcoal in a fine silt matrix (Jones 2016; Jones et al.

Figure 2.7: Stand of *Phragmites* spp. in Ral Ral Creek. Photograph: M. Morrison Sept. 2015.

Figure 2.8: Stand of *Typha* spp. in Ral Ral Creek. Photograph: R. Jones May 2019.

2017; Westell and Wood 2014:46). Surface surveys indicated the presence of freshwater mussel shell fragments on 44% and 50% and 40% of the mounds recorded on the Chowilla[5], Katarapko[6] and Calperum floodplains respectively (Jones 2016; Westell and Wood 2014:46). This potentially indicates the use of river mussel as a food source (and/or as tools) and their preparation within or near earth mounds (Jones 2016:97; Jones et al. 2017; Jones et al. 2022). Mounds in this region are closely associated with major anabranch channels and the margins of billabongs which are prevalent in areas of the floodplain that were regularly subject to seasonal inundation prior to the regulation of the river. These environments are prime habitats for emergent macrophytes such as *Phragmites* (common reed) and *Typha* (bulrush) spp. (Figures 2.7 and 2.8) (Jones et al. 2017; Jones et al. 2022; Westell and Wood 2014:48). Mound contents, morphology and distribution, suggest formation processes associated with the repeated use of earth ovens and the consequential accumulation of residues including charcoal and degraded heat retainer material. Mounds were likely separated from habitation and other activity areas which were most often located on raised areas of sand (which were more suitable for occupation than the surrounds of ashy earth mounds) resulting from prior river migrations (Jones et al. 2017; Westell and Wood 2014:48). This represents the key explanatory model for formation of mounds in the South Australian Riverland.

1.7.1.2 Western, North-Western Victoria and Central Murraylands

Early Victorian earth mound research was conducted by Coutts et al. (1976:42–43, 1979) in the western plains and Murrayland regions of Victoria, including Swan Hill and the Lodden, Avoca, Little Murray and Murray River regions (Figure 2.10) of northern Victoria (Coutts et al. 1979; Lane 1980). As with previous work in the north-west and western regions of Victoria, the survey aimed to record mound chronology, functions, cultural relationships, site type and variety, as well as the future research potential of this region. Initially two types of mounds were recorded in the Nyah Forest, comprising a total of 122 sites (Coutts et al. 1979:15, 54). The mound types were differentiated on content, the first containing burnt clay, charcoal and ashy sediment, whilst the second type also contained freshwater mussel

[5] A word derived from the local Aboriginal language said to mean ‘a place of spirits or ghosts’ (Tindale c.1934–c.1991).

[6] A word derived from the local Aboriginal language said to mean ‘home for rock crystal’ (Tindale c.1934–c.1991).

shell and other faunal remains. These were generally less than 20 metres in diameter and often located in groups (Coutts et al. 1979:15–17). Following excavation of mound DP/1, it was concluded the site had developed into a regular seasonal occupation space following original establishment as a cooking mound (Coutts et al. 1979:81). The regular use of the site suggested it allowed greater seasonal access to abundant wetland areas and increased sedentism (Coutts et al. 1979:82, 86). The excavation of two smaller mounds (DP/2 and DP/3), which were in close proximity to the larger occupational mound (DP/1) outlined previously, indicated intensive use as earth oven sites (Coutts et al. 1979:84–85). The excavation of a third mound indicated similarities to DP/2 and DP/3, except that it contained artefacts and extensive faunal remains; and was considered to have been used during periods of flooding (Coutts (1980:36). Figure 2.9 shows the chronological relationships within this mound complex. Lane's (1980:110–118) survey of the Little Murray River, an anabranch system of the Murray River, near Swan Hill in north-western Victoria (Figure 2.10), recorded 83 earth mounds. These were damaged through farming, following the European invasion in the mid- 19th Century (Lane 1980:113–117). Mound contents included nodules of burnt clay, charcoal, ashy sediments and fragments of mussel shell and bone. Two mound types were identified due to differences in morphology (Lane 1980:115).

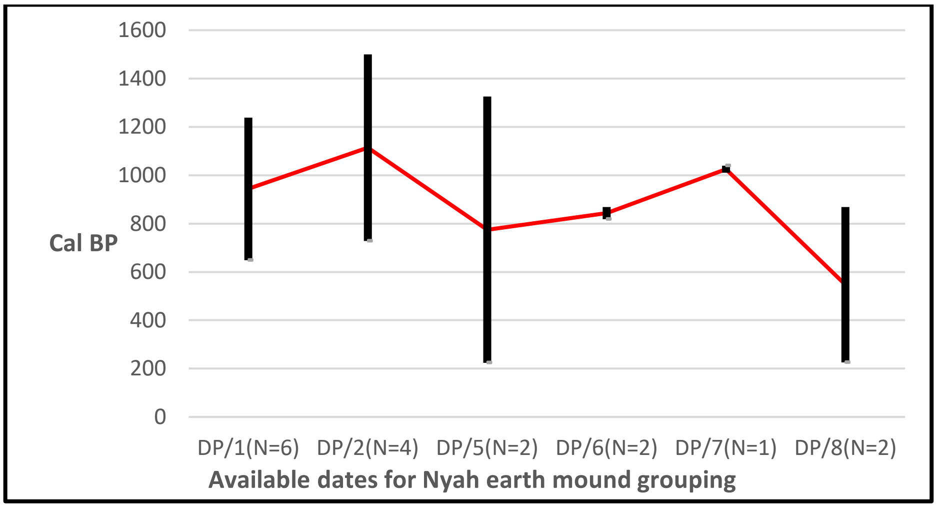


Figure 2.9: Chronological relationship of the Nyah mounds discussed above using the median value of each calibrated range of the 17 dates (Coutts et al. 1977, 1980; Godfrey et al. 1996).

Two types of earth mound were also recorded during additional surveys of the Nyah Forest region (Figure 2.10) (Sullivan 1980). Mounds, classified as 'compact' were located on the levee banks of floodplain creeks, and contained burnt clay nodules with very little cultural material. An additional type, which were greater in size but less frequent, were described as 'soft' mounds. The latter were considered to have been developed over the smaller compact mounds. An analysis of mound sediment pH indicated a lower range (5.5 to 6.5) for smaller mounds and a higher range (8.0 to 9.0) for the larger mounds (Sullivan 1980:49–51). This anomaly was considered to be related to use and development differences rather than post-depositional factors (Sullivan 1980:50).

Age determinations of mounds located in close proximity within the Nyah Forrest potentially demonstrate the contemporaneity of a satellite grouping which was periodically active between the period ~200 to 1,400 cal BP (Figure 2.9) (Godfrey et al. 1996). Such an association may suggest sedentism oriented around a mix of larger and smaller mounds with each type representing dedicated living spaces and cooking sites respectively.

In the Hopkins River precinct of Western Victoria (Figure 2.10), mounds were concluded to be functionally non-specific seasonal camps, located close to water, and represented a diverse range of activities (Coutts et al. 1976:43). Two hundred and seven mounds, generally circular in shape were recorded, of these 45% were grouped in pairs within larger groupings of six with 75% located on natural rises (Coutts et al. 1976:12–13, 19–20). Two mound excavations contained stone artefacts, burials, stone hearths and faunal remains consisting of mammals, reptiles, freshwater shellfish and crustaceans (Coutts et al. 1976:20–38). In contrast, mounds located to the north, along the Murray River, contained large quantities of freshwater mussel shell, burnt nodules of river clay and bone (Coutts et al. 1976:4–6, 1979:77–84).

Three earth mound morphologies were identified from early research in Victoria (Coutts et al. 1979:1). These were:

- A deposit consisting of a single layer containing charcoal pieces and burnt clay nodules. Classified as type A.

- A homogenous raised feature containing large amounts of burnt clay, mussel shell and animal bone. Classified as type B.
- Raised occupation sites containing stone flakes and stone tools, hearths, ovens, pits, and faunal remains, including mollusc shell and eggshell fragments. Classified as type C.

The three broad mound classifications listed are not necessarily represented in any one locality. Mounds can also differ in morphology, potentially reflecting a developmental continuum over time where individual mound remains reflect its stage of development (e. g., type B represents an early stage of development, type C represents a stage of continued development and use as seasonal occupation space and type A represents a terminal stage following erosion and abandonment) (Coutts et al. 1979:1, 85–86).

Pardoe and Hutton (2020:5) recorded 153 mounds at Pollack Swamp between Swan Hill and Echuca. Using LiDAR data, they established a strong correlation between mounds and water features including ephemeral channels only filled during times of flood (Pardoe and Hutton 2020:6). Pardoe and Hutton (2020:14) described the entirety of Pollack Swamp as a 'village site' with an estimated population of 250–500 people in residence for five months per year, supported by a highly productive wetland environment. Mound dimensions were similar to others recorded in the central Murray vicinity (Pardoe and Hutton 2020:5; see Figures 2.5 and 2.6)

Following Coutts et al. (1976, 1977, 1979), Williams (1988:72–75) identified three types of earth mounds in the Caramut area of the western district of Victoria (Figure 2.10), including oven sites, shelter spaces and general living areas, although these functions could be combined together in the one location. Through a combined approach, utilising ethno-historical information, archaeological excavation and soil chemistry, Williams (1988:67) concluded that clusters of Caramut mounds represented base camps and potentially established villages. Williams (1988:216–222) hypothesised that earth mounds in south-western Victoria were an adaptation to wetland environments, were formed from general occupation debris and constituted semi-sedentary camp sites associated with the capture of eels known as *kooyang* (*Anguilla australis*), indicating the development of a more sedentary lifestyle based on the seasonal exploitation of this species. In some respects, the exploitation of eels is analogous to the intensive exploitation of emergent macrophytes in earth oven mounds along the Murray River, in the sense that large quantities of a resource (eels) were processed (smoked) in specific structures (hollow trees) (Builth 2002; Builth et al. 2008; Williams 1988).

Williams (1988:215) further argued that large mounds represented 'a change in the organisation and structure of a campsite' which represented a continuum of construction, a reduction in mobility, long-term occupancy of sites and 'a change in the use of labour'. This constituted a focus on the development of large mounds and large-scale durable stone complexes for eel management and harvesting (Williams 1988:215). Williams (1988:220–221) discounted the influence of environmental change as an influence in this context, concluding that the appearance of such structures was related to intra and inter group social and economic influences. Williams (1988) further posited that these structures derived from changes in alliance and redistributive networks, resulting in a higher demand for food and consequently a transition which added a seasonal food production system (based on eel management and harvesting) to existing subsistence procurement strategies.

The study by Builth et al. (2008:413, 422) identified evidence from palaeoecological analysis of sediment cores which indicated the onset of a drier and more variable climate (associated with ENSO activity) from about 4,000 cal BP in western Victoria. They linked this development with an increase in management activity and landscape modification. The latter involving the construction of dams which guaranteed permanent water and enhanced eel productivity despite lower water rainfall on the Mt Eccles lava flow, near Caramut in western Victoria, at this time (Figure 2.10) (Builth et al. 2008:422; see also Clarke 1994:1–15 for a contra account).

2.7.1.3 Southern and Western New South Wales

A survey of a system of lakes and channels between Nyah, on the Murray River, and the Wakool River in New South Wales, within the central Murray River floodplain (Figure 2.10), identified 70 earth mound sites (Simmons 1980:57–86). The survey included an examination of mound morphology, structure and contents; and regional geomorphology. Two types of mounds were recorded between Lake Jilleroo and Tooley Landing, near Wakool. Large, isolated mounds 30–40 metres in diameter and up to 0.75 metres high, similar to the 'type two' described by Coutts et al. (1979:15) at Nyah Forest, were located along the main-stream levee (Simmons 1980:64–65). Clusters of a second, smaller type of mound, were found near the edge of the floodplain. The area between Nyah and the Wakool River, contained small mounds within alluvial flats and lake margins (Simmons 1980:69–70). Based on spatial arrangement and contents, Simmons (1980:83) concluded that the mounds were associated with the exploitation of aquatic plant resources.

Buchan (1980) reported two types of earth mounds in the Lake Coomeroop region of the Murray Valley, in southern New South Wales (Figure 2.10). Dark silty sediment, charcoal, burnt clay nodules, mussel shell and a range of faunal remains were characteristic of larger mounds. Smaller mounds were circular with a low profile with nodules of burnt clay and occasional mussel shell (Buchan 1980:46–47). The identification of anthropogenically derived earth mounds was complicated by the presence of ashy earth features formed around naturally burnt tree stumps and root systems which were similar in appearance to culturally derived mounds. On investigation, it was concluded that cultural and natural features were distinguishable through morphology and contents (Sullivan and Buchan 1980:96). The key identifiers for anthropogenic mounds were a flat base, dark compact sediment and steep sides. In addition, the magnetic profile of burnt sediment obtained from a magnetometer survey of Aboriginal mound sediments at Nyah assisted with the identification of Aboriginal mounds and distinguished them from features created by wild fires (Elliott 1980:108).

Later field surveys and excavation in the Wakool River region, and a further study at Caramut in western Victoria (Figure 2.10) by Frankel (1991) noted a close association of mounds with water, the habitat of emergent macrophytes and access to aquatic resources, particularly during periods of inundation (Berryman and Frankel 1984; Frankel 1991:77–82, 82–84). The 95 mounds recorded demonstrated an alignment with the mound typology established by the earlier work by Coutts et al. (1979) (Berryman and Frankel 1984:25–28).

Klaver's (1998:132–135) work in the central Murrumbidgee floodplain, resulted in the documentation of 311 mounds which were located near water features. Sites identified included earth ovens, heat retainer concentrations, hearths, mounds and occupation sites (Figure 2.10). The principal material recovered from the excavation of four mounds and two earth ovens were nodules of burnt clay and some faunal remains (Klaver 1998:172–181). Klaver (1998:278–284) concluded that the repeated use of earth ovens was the key process associated with the origins of earth mounds, noting that some mounds were enlarged to provide greater seasonal occupation space over time. Klaver (1998:4–5, 281, 286) argued that the evidence suggested the application of novelty in procurement strategies, and increased flexibility in resource utilisation, but did not indicate demographic change or increased sedentary behaviour because of the difficulty of differentiating between long term occupancy and short occupation events. Klaver (1998:278) also noted the absence of any patterning in flaked stone artefacts at the Cooey Point Lagoon site in the Murrumbidgee region, labelling the scatter as 'a deflated accumulation of materials' with insufficient densities suitable for analysis because of post-depositional processes.

Two hundred and eighty six discrete ashy deposits were reported by Pardoe (2003:45) for research conducted within the Menindee Lakes region of far western New South Wales (Figure 2.10). These were described as 'focal points where dense occupation occurred over extended periods of time' (Pardoe 2003:45) and were considered to have developed from earth ovens and were 'in many ways they are similar to the black earth mounds of the Riverine Plain' (Pardoe 2003:45; see also Martin [1996, 1999] and Pardoe and Martin [2001]). Pardoe (2003:45) hypothesised a likely association of such sites with the intensive cooking of meats, rhizomes and tubers as well as fibrous vegetables. Pardoe (2003:45) also included the production of twine for netting as a by-product of this activity, citing ethno-historical sources for the link between earth ovens, *Typha* root fibre, twine production and local trading practices (see also Brock 1844 [1988]:52; Howitt 1904:717).

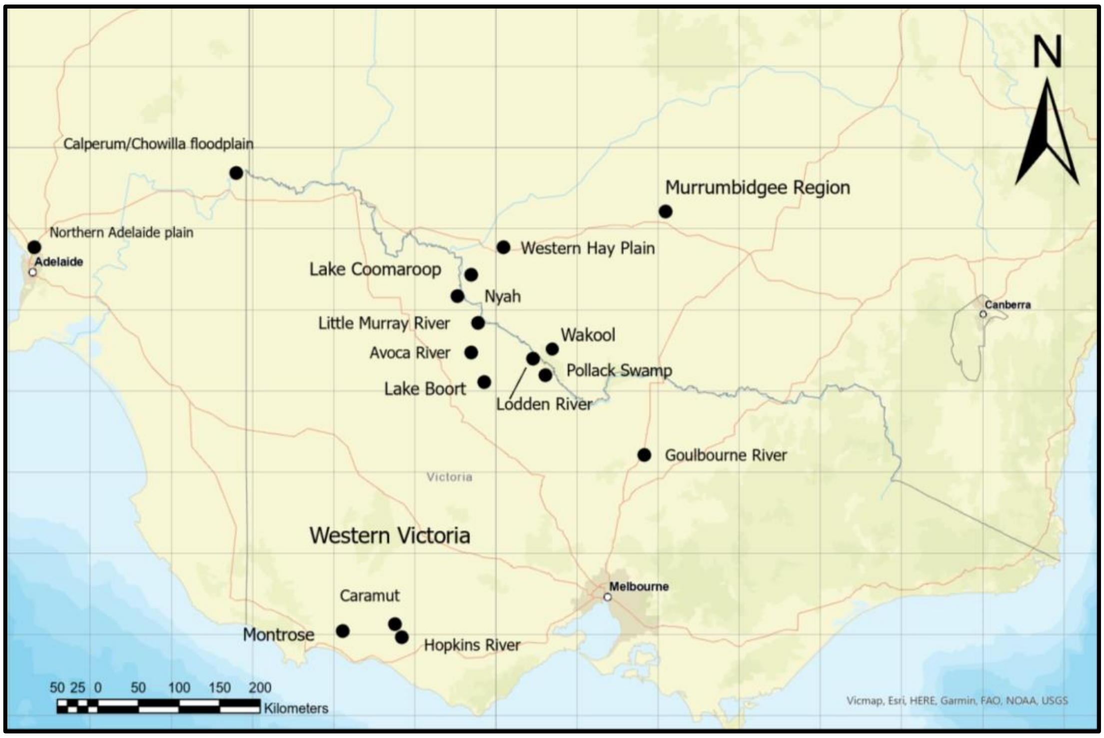


Figure 2.10: Mound precincts of the central Murray, Murrumbidgee, western Victoria, Calperum and Chowilla floodplains in the South Australian Riverland and northern Adelaide Plains regions.

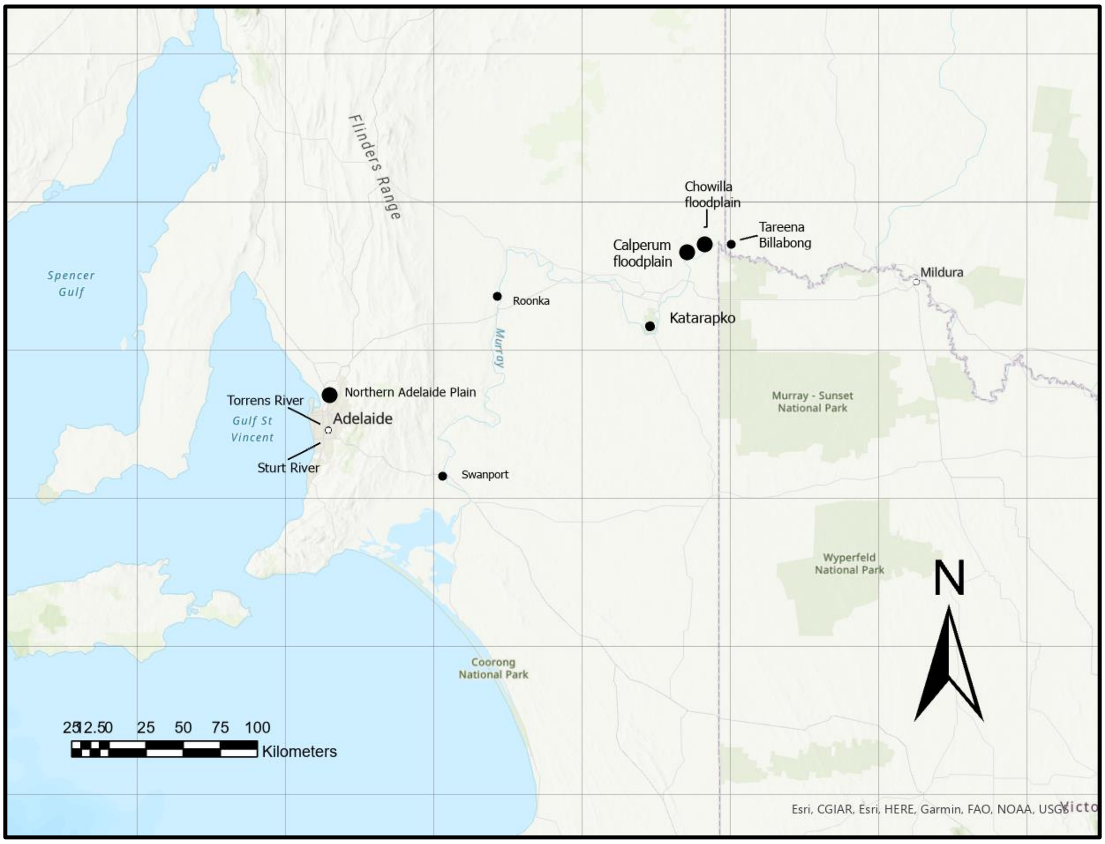


Figure 2.11: The location of the Roonka and Swanport burial sites, Tareena Billabong and key South Australian mound locations.

2.7.1.4 Northern New South Wales

Balme and Beck (1996:39–49) recorded 63 mounds within the Macquarie Marshes (Figure 2.1) noting that mound contents included burnt clay nodules 5–25 mm in size in accumulations of greater than 10 square metres and were situated in seasonally flooded areas (Balme and Beck 1996:40–42). Spatial, dimensional and compositional information compiled from their research was compared with earth mound research data from other locations in south-eastern Australia. From their analysis, they noted that earth mound distribution is not uniform through the MDB (see Figures 2.1 and 2.10 for a regional perspective), suggesting the existence of a diversity in intra-regional resource procurement strategies, despite similar environments (Balme and Beck 1996:48).

2.7.1.5 Hay Plain

The Hay Plain is located in south-western New South Wales, south of the Murrumbidgee River and north of the main channel of the Murray River (Figure 2.10). The region has an area of approximately 20,000 square kilometres containing a network of irrigation and natural water courses, where some of the latter have been co-opted in recent times for irrigation channels. Natural water courses and wetlands are often associated with earth mounds (Witter 1982, 1992:141). In the western portion of the Hay Plain, earth mounds range from very large to very small and can be found in complexes. Martin (2006:296–299) found a relative concentration of earth mounds in association with '...larger, richer, more predictable and permanent wetland features'. Earth ovens and mounds are found along paleo-channels to the east, and mounds, ovens, middens and ashy archaeological deposits along the Lachlan and Murrumbidgee rivers (Klaver 1988; Martin 1996a, 1996b).

Through her research, Martin (2006:45–46) sought to identify a 'fundamental factor' which could be linked to the emergence and development of earth mounds within the Hay Plain. This eventuated in an investigation of behavioural change, the role of women and socio-economic reorganisation within the framework of natural and cultural landscapes of the region. Ethno-historical and archaeological analyses led Martin (2006:292–293) to discover the earliest Australian evidence for the intensive use of heat retainer technology at about 4900 cal BP on the Hay Plain. Martin (2006) concluded that this involved the cooking and processing of plant tubers and rhizomes. Slow cooking in a low oxygen environment allowed the release of easily digested starches and sugars from the normally indigestible complex carbohydrates stored by tuberous plants. The archaeological evidence provided by the Ravensworth 3 and Tchelery 1 mound excavations demonstrated the use of heat retainer ovens through the presence of clay heat retainer nodules, fused silica, charcoal, lenses of ash, pits and hearths (see also Martin 2006:293). An absence of definite stratigraphic relationships through a thorough mixing of mound contents over time indicated repeated use of the sites. Magnetic susceptibility and particle analysis indicated that the source of the finer sediments present in the excavations was linked to the breakdown of clay heat retainer material by mound formation processes. The extensive use of wetland plants such as *Typha* and *Cyperaceae* spp. was evidenced through pollen studies, charcoal analysis and imprints of plant material on baked clay nodules. When correlated with the relatively small amounts of shell and bone present, the evidence indicated that plants (particularly *Typha* and *Bolboschoenus* spp.) were the source of the principal material cooked in the mounds excavated (Martin 2006:294, 2011:162–172). Martin (2006:294) concluded that:

> …the mounds of the Hay Plain derive largely from the repetitive use of baked clay heat retainer ovens in a designated, bounds locale, primarily to cook carbohydrate rich plant food such as *Typha* rhizome.

2.7.1.5 The MDB socio-economic context

Previous archaeological research into burial practices, subsistence systems and the physical and health status derived from osteological studies of MDB populations, provides a unique opportunity to explore a socio-economic context within which earth mounds emerged. Major cultural change has been hypothesised to have occurred within populations of the MDB from the early Holocene. This has been signalled by evidence of large Aboriginal cemeteries, population growth, sedentism, increasing territoriality and exclusion (Lourandos 1997:233; Pardoe 1995:705–706; Owen 2004; Pate and Owen 2014:91–92; however, see Hiscock 2008:257–259 for a different perspective on this issue). Pardoe (1988:12–14) has argued that the archaeological record, from the period 2000 cal BP to the present, potentially indicates the emergence of hierarchical authority structures associated with sex and age, social status by descent and changes in social organisation. Skeletal studies have indicated an increase in skeletal trauma, disease and arrested growth in individuals which hint at organised conflict between groups and periodic famine (Pardoe 1995:711). Pardoe (1995:708) noted that native yams and *cumbungi* (*Typha* spp.) became a significant food component and fibre source in the MDB with increasing density of occupation during the early Holocene. He notes the appearance of tooth wear patterns suggesting the intensive processing of string, using teeth, from about this time (Pardoe 1995:708).

In critiquing this hypothesis, Hiscock (2008:257–259) suggested that the Aboriginal skeletal evidence potentially supports other interpretations. The cemetery at Roonka in South Australia, for instance, has an average burial rate of one individual every two or three generations (Littleton and Allen 2007:283–298). This rate of interment may not necessarily reflect hierarchical social structures, exclusivity or continuity of use by a single group. Alternatively, the evidence may reflect use of this location by different groups which were small, mobile and not fixed to a specific location (Hiscock 2008:259; Littleton and Allen 2007:283–298).

Also, an isotopic study of ancestral Aboriginal skeletal remains found near the River Murray in South Australia at Roonka Flat near Blanchetown and Swanport near Murray Bridge, shows that adult Aboriginal males living in this region had a significantly different diets than other group members (Pate 1998a, 1998b, 2006:232, 240; Pate and Owen 2014). Adult males had a higher percentage of meat in their diets in contrast to females and juveniles whose diets were dominated by plant and aquatic foods such as fish and freshwater mussels. From this evidence and a study of mortuary practices, Pate (2006:239) concluded that social differentiation by gender and age was related to subsistence and was not indicative of social stratification by hereditary decent.

Dental studies on past populations of the MDB indicate the consumption of coarse and gritty plant foods were possibly associated with earth oven cookery and the processing of fibre for twine through the use of teeth (Pardoe 1995:710–711). This finding is potentially related to the intensification of food procurement strategies, associated social change and population growth as argued by Pardoe (1995). The analysis of skeletal remains from Murray River populations dated from the early to late Holocene indicated the presence of a high incidence of chronic and acute stress, including dental enamel hypoplasia (anaemia) and cribra orbitalia (Webb 1984). Webb (1984) argued that this reflected a high prevalence of infection, malnutrition, parasitism and endemic treponematoses and a large relatively sedentary population subject to high mechanical stress. In fact, this health profile was considered to be more typical of a sedentary, early stage ‘agricultural society’ than that of traditional ‘hunter-gatherers’ (Webb 1995). Pardoe (1995:710–711) noted that the health profile outlined above was not evident in Darling River and Willandra populations, signalling potential changes in social systems and economic strategies within those populations where it did occur.

The studies outlined above in this section provide general insights into Aboriginal lifeways within the MDB during the Holocene. Skeletal studies of ancestral populations indicated the occurrence of nutritional stress in floodplain populations which was probably associated with high territoriality, seasonal variation in resource availability and high population levels. Dental evidence suggests the wider adoption of earth oven cookery and the processing of large quantities of fibre from *Typha* spp. (Pardoe 1995) which correlate to the emergence of earth mounds in some floodplain environments of the MDB during the mid Holocene. Isotopic analysis of skeletal material potentially suggest changes in socio-economic practices associated with the establishment of earth mounds in such environments, including a reorganisation of group resources and the socio-economic role of women, in response to external challenges.

2.7.2 Northern Australia

2.7.2.1 Northern Cape York

Aboriginal earth mounds are located in the north-western coastal region of Cape York in both the Weipa, Mapoon and Aurukun regions (Figure 2.12a, b). At this time there has been little survey and no published data of earth mound structures in other parts of northern Cape York.

At Aurukun earth mounds are strategically located between resources zones, on relic dunes and silt plains, and close to freshwater wetlands (Figure 2.12a) (Brockwell 2006a:47). At Weipa earth mounds cluster on the margins of freshwater floodplains and creeks (Figure 2.12b) and contain burnt termite mound material which is theorised to have been used as heat retainer material in earth oven cooking, this contrasts with the MDB where floodplain clay is the common heat retainer material (Brockwell et al. 2017:129; Coutts et al. 1976, 79;

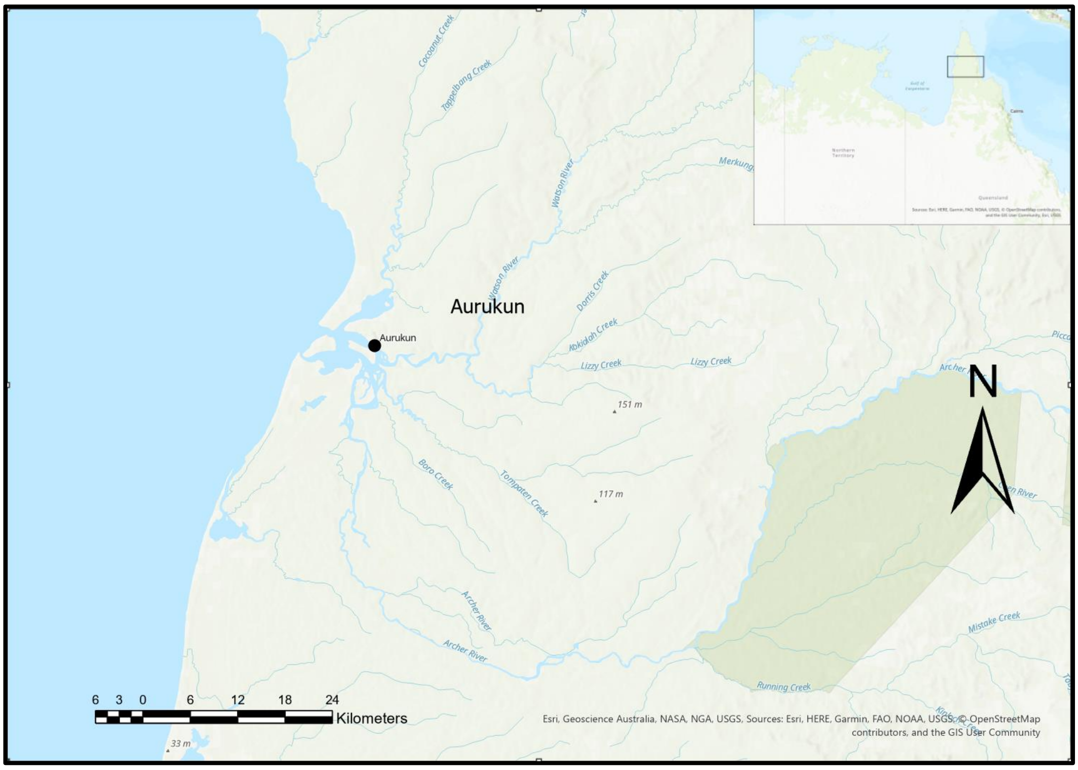


Figure 2.12a: Map of Aurukun township and surrounding areas.

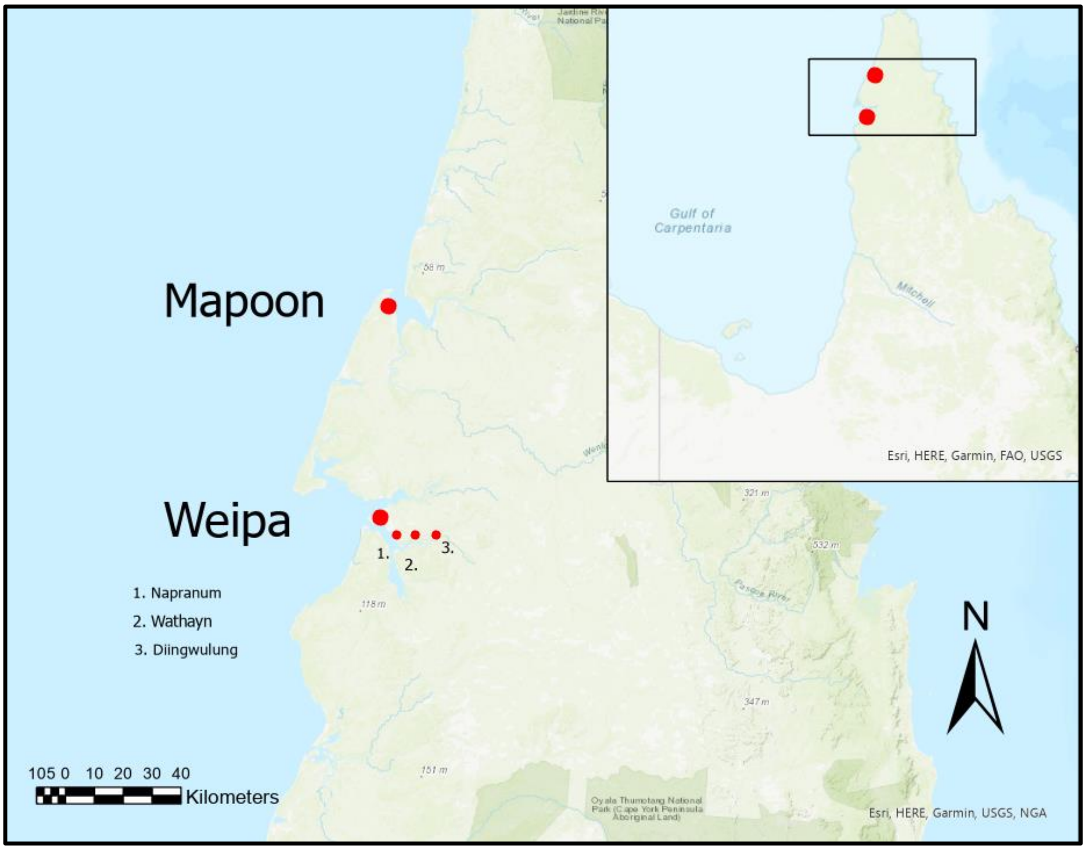


Figure 2.12b: Map of mound locations, Mapoon township, Weipa township, and the Aboriginal community of Napranum in northern Cape York.

Jones et al. 2017). Shiner and Morrison (2009) reported 35 earth mounds in their heritage survey of the bauxite plateau east of Weipa. The mounds range from 5–12 m in diameter Diingwulung (n = 21), and are located on floodplain margins and near estuarine sections of freshwater creeks and rivers (Shiner and Morrison 2009).

Conyers et al. (2019:4) identified in excess of 250 mounds in a linear cluster north of the Mapoon township using physical survey (n = 20) and analysis of LiDAR data (n = 250+). A surface and geophysical investigation using GPR and magnetometry of six of these mounds suggested the presence of human burials, modified and burned surfaces. Oral histories from Elders in the Mapoon area confirmed the use of some mounds as burial sites and associated ritual activities (Conyers et al. 2008:10; see also St Pierre et al. 2019 and Sutton et al. 2019).

Conyers et al. (2019:11) also suggested that in the context of burials, there is '…some surety that the construction of mounds in this area of Mapoon was monumental and likely has a long history.' Conyers' et al. 2019 analysis suggests ritual and burial as likely formation processes for mounds located in the Mapoon region and up to 50 cm in height (Figures 2.14 and 2.15; see Figures 2.5 and 2.6 for similar data for MDB mounds). At Weipa, mounds clustered at Peppan Creek (n = 9), Wathayn (n = 5) and and Diingwulung (n = 21) and are located on floodplain margins and near estuarine sections of freshwater creeks and rivers (Shiner and Morrison 2009). In addition, Ó Foghlú (2021) conducted an extensive analysis of earth mounds (n = 14) in the Waythan and Diingwulung areas including excavation and sediment analysis.

2.7.2.2 Northern Territory

Brockwell (2006a:49) lists 137 earth mounds which had been recorded in eight subregions of the northern portion of the Northern Territory. These include Milingimbi, the Arafura Swamp, Blyth River, South Alligator River, Mary River, Adelaide River, Hope Inlet and the Reynolds River (Figure 2.13) (Brockwell 2006a:48–53). See Figures 2.14 and 2.15 for dimensional data of northern mounds by mound precinct.

2.7.2.3 Milingimbi

Roberts (1991:119, 122) reported a complex group of occupation sites at Milingimbi, of these 15 were identified as remnant earth mounds which were located on dunes amongst grasslands and swamps, near mangroves and mudflats. Specific types of sites noted included

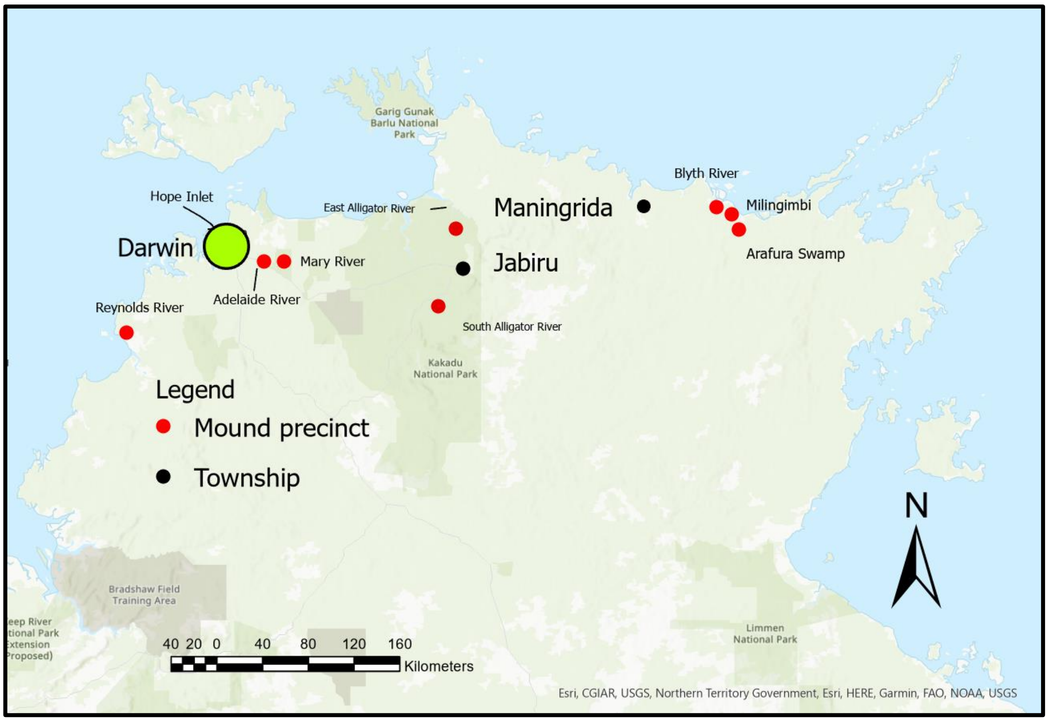


Figure 2.13: Map of key mound locations and the nearby communities of Jabiru and Maningrida in the Northern Territory.

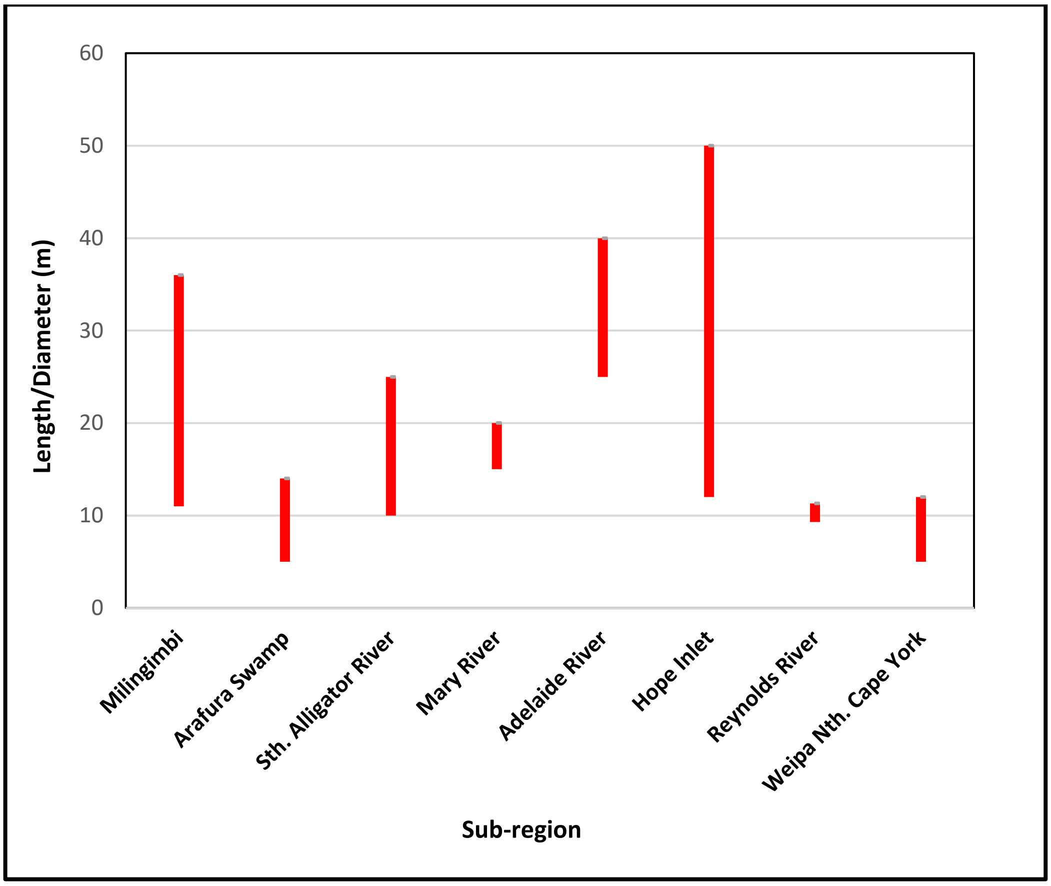


Figure 2.14: Length/diameter range of recorded mounds in the Northern Territory and Weipa in northern Cape York (adapted from Brockwell [2006a], Shiner and Morrison [2009]).

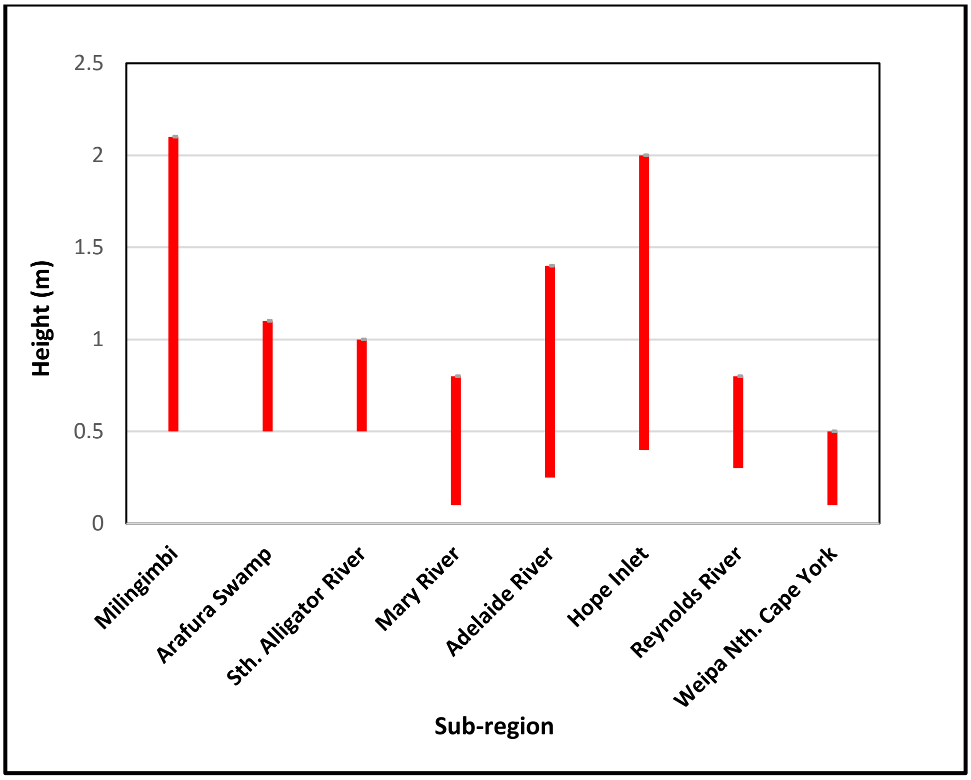


Figure 2.15: Height range of recorded mounds in the Northern Territory and Weipa (adapted from Brockwell [2006a], Shiner and Morrison [2009]).

mounded middens, earth mounds, conical shell heaps, home base mounds and natural (geomorphic) mounds of shell, noting considerable damage from recent (at the time) construction activity (Roberts 1994:178, 180–181). The earth mounds were elliptical in shape rising in some cases to over two metres, composed mostly of sand and humic soil with some cultural material present which included shell (*Tegillarca granosa),* ash and turtle remains. Roberts (1994:180) suggested megapode activity as a major contributor to earth mound formation, although Brockwell (2006a:48) noted ethnographic evidence that suggests human activity to be the major factor in formation. Roberts (1994:183) himself later indicated that such sites constituted dinnertime camps and were a major focus of subsistence activity by Aboriginal people, however he maintained the potential for dual agency and noted that additional research is required for confirmation of this (see also Stone (1989).

2.7.2.4 Arafura Swamp

Peterson (1973) first reported mounds in the vicinity of the Arafura freshwater swamp, typically located on a sandy delta environment at the intersection of a variety of resource zones (Figure 2.13). These included freshwater wetlands, monsoon rainforest, open forest and seasonal water bodies (Peterson 1973:173, 175, 181, 186). A cluster of 17 mounds with an average diameter of 9 m contained a variety of faunal remains including reptile, freshwater fish, turtle, wallaby and freshwater mussel. Other material included termite mound heat retainer, edge-ground axes, paperbark food wrapping, grinding material and flaked stone artefacts (Peterson 1973:192). Peterson (1973:177) concluded that the mounds resulted from an accumulation of earth oven heat retainer material resulting from repeated cooking events. Such sites were associated with resources which were subject to the seasonal flooding cycle and considered to be due to a regular pattern of behaviour from at least 1400 cal BP, based on a date obtained at Milingimbi (Peterson 1973:189–190). Ethnographic observations indicated that local people continued this subsistence cycle at the time of reporting (Peterson 1973:177, 187–188).

2.7.2.5 Blyth River

Earth mounds were reported around Balpilja freshwater swamp in the Blyth River region (Figure 2.13), one of which was noted to be 20 m in length, 10 m in width and 2 m in height (Brockwell 2006a:49). Meehan (1988:2, 1991:205) reported bone, shell, eggshell and stone artefacts in these sites and indicated their location at the junction of swamp and open woodland. Brockwell et al. (2005:86) reported a basal date of 1005 cal BP for a large mound on the edge of Balpilja swamp.

Meehan (1988:2–13, 1991:205) noted from ethnographic observations that repeated earth oven use and the build-up of termite mound heat retainer material was the process responsible for earth mound formation. Foods cooked in the earth ovens included wallaby, geese, duck and turtle during periods of occupation during the early dry season whilst swamps were still full of water (1988:2–13, 1991:205). During this time spike rush corms (*Elocaris dulcis*) and water bird eggs were also exploited. Meehan (1982:179) recorded 32 ‘dinnertime camps’ and two home bases occupied by the An-barra in April 1973 (early dry season). Meehan (1988:13) also noted that the mounds of the Blyth River had a spiritual significance for local people.

2.7.2.6 Alligator Rivers Region

Brockwell (2006a:49) noted that 13 earth mounds were reported on the South Alligator River floodplain (Figure 2.13), as well as the presence of others along its tributary, Magela

Creek. More recently Brockwell et al. 2020 excavated a shell midden (Djindibi 1) and an earth mound (Myaranji 1) which were located between the East and South Alligator Rivers (Figure 2.13) (Brockwell et al. 2020:80–94). They concluded from differences in estuarine faunal remains from each site that Myaranji 1 was occupied during the wet season and Djindibi 1 during the dry (Brockwell et al. 2020:91–92).

Meehan et al. (1985) investigated a site at Kina, on the eastern side of the river, which was located on a peninsula surrounded by a freshwater billabong, noting an extensive scatter of stone artefacts and several mounds containing freshwater mussel shell. Meehan et al. (1985) excavated a large 50 m by 40 m mound finding a faunal assemblage including freshwater mussel, mangrove shell (*Polymesoda erosa*), freshwater turtle and estuarine fish. Meehan et al. (1985:148–150) identified a two-fold occupation sequence with a proportional change in lithic material as well as mussel shell frequency increasing over time. A sample above the basal level was dated to 444–145 cal BP (ANU-3212) but the presence of mangrove shell in the lower levels of the site potentially indicated an older date for the basal level (Meehan et al. 1985:147,152). Additional mounds, one group of three and another of six, were identified north of Kina adjacent to a relict river channel (Brockwell 1983, 1989:158–162, 1996). At Malakanbalk, west of the South Alligator River, three earth mounds 30–40 m diameter and 0.5–1 m in height, were recorded on a headland extending into floodplains adjacent to the main river channel (Meehan et al. 1985:126–127). These were situated in monsoon forest, covered in grey silt and had a high density of stone artefacts (Meehan et al. 1985:126). Brockwell suggested that due to location and the local resource base they were likely occupied during the wet season (Brockwell 1989:212, 1996).

Woodroofe et al. (1988) reported four earth mounds near the mouth of the South Alligator River, ranging from 15–20 m in diameter and up to 0.5 m in height and composed of shell, silt and/or clay containing bone and rock fragments and stone artefacts including grinding material. One mound also contained a human burial. Ages of 1774–1100 cal BP to 5054–4390 cal BP (ANU-4047, ANU-3992) over five separate samples of shell (Appendix Nine) was also reported by Woodroffe et al. (1988:96–97). Woodroffe et al. (1988:99) concluded from the lithic assemblage that the mounds were multifunctional and coincided with the ‘freshwater phase’ associated with this region (see Chapter Five for a more detailed discussion).

The faunal and artefactual contents of earth mounds from the Alligator Rivers region indicate their primary purpose as living space, serving as elevated areas which assisted the exploitation of surrounding wetlands during the wet season (Woodroofe 1988:99).

2.7.2.7 Mary River

As cited by Brockwell (2006a:51), Baker (1981) identified 12 earth mounds located in two distinct mound precincts at the Mary River (Figure 2.13), these were black soil floodplains and coastal beach ridges. Other site types included artefact scatters, shell mounds, sites with pounding hollows and contact sites (Baker 1981:74–75, 80–81). Earth mounds found on the black soil floodplains contained mangrove shell, stone artefacts and pounding tools whilst coastal earth mounds had a lower density and a range of lithic material with little shell present (Baker 1981:74–75). Baker (1981:80–81) concluded from the location and the nature of the assemblages, that black soil floodplain mounds were early or late wet season sites whilst coastal earth mounds were primarily used during the wet season.

2.7.2.8 Adelaide River

Thirty earth mounds have been recorded on the western side of the freshwater floodplains associated with the Adelaide River (Figure 2.13), clustered on two headlands located on the edge of the floodplain (Brockwell 1996b, 1996c, 2001a:70–76, 2005:10–11; Smith 1981). All were close to freshwater lagoons, open woodland, monsoon forest, creeks and water holes; and associated with artefact scatters, ponding hollows and rock quarries. Excavations from five mounds provided lithic artefacts and faunal remains (Brockwell 1996c, 2001a:141–172; Schrire 1968; Smith 1981). Dating indicated occupation from 4340–3732 cal BP (WK-5796) until modern times during the evolution from estuarine to freshwater environments (Brockwell 2001b:80–84, 2009). Via a consideration of the faunal assemblage Schrire (1968) considered the mounds to be occupied during the wet season, however, from a reconsideration of the faunal evidence and site location, Brockwell (2001a:200–201, 2005:16) concluded that occupation on mound sites occurred in the early dry season as a base for exploitation of nearby ephemeral wetlands. Brockwell (2001a:181, 193, 2006a:52) also speculated from ethnographic evidence that the mounds may have constituted cultural markers of boundaries.

2.7.2.9 Hope Inlet (Darwin)

Eighteen earth mounds were recorded at Hope Inlet (Figure 2.13) interspersed with shell mounds (Bourke 2000:97, 2004; Burns 1999:64–67, 430–434). An excavation of a mound (HI97) classified as coastal/estuarine, demonstrated a shell content one third of that of nearby shell mounds, a relatively low lithic density and a basal date of 11,580–1064 cal BP (WK-6526) (Bourke 2000:225). Faunal remains included macropod, snake, rodent, crab and fish (Bourke 2000:228–229). Bourke (2000:233–234) concluded, from the presence of ash, burnt shell and burnt termite mound material, that the mound was derived from earth oven use. Burns (1999:67) and Bourke (2000:44) concluded that the mounds of Hope Inlet were occupied in the wet season as an elevated space which provided refuge from flooding and convenient access to several resource zones. This is analogous to the development of some individual earth mounds in floodplain locations of the MDB which enabled continued access to resources during periods of flooding (Coutts et al. 1976, 1977, 1979).

2.7.2.10 Reynolds River

Forty six earth mounds were reported on the plains of the Reynolds River (Figure 2.13) (Guse 2005:110–111; Guse and Majar 2000). Other sites which were associated with mounds included shell middens, artefact scatters, grinding hollows and quarries. Two types of mound were identified from differences in location and contents. The first type were located on chenier beach ridges, with a base of chenier shell topped with the remains of edible shellfish in a humic matrix capped by an earth layer. The second type were found at the junction of lowlands and freshwater floodplains within 500 m of freshwater billabongs, with little shell present. Floodplain mounds were located on small natural rises, usually at the juncture of several resource zones, which was the basis for repeated use and consequently the formation of a raised surface (Guse 2005:116). Guse (2005:116) attributed the high presence of grinding material to the processing of aquatic plants from nearby wetlands. Guse (2005:116–117) also noted that the presence of useful nut trees, fruit trees and edible tubers on mounds in this location would have enhanced reasons for repeated occupation. Dates of 3553–3020 cal BP (WK-7170) and 4685–4093 cal BP (WK-7432) were obtained from two chenier mounds and dates of 295–0 cal BP (WK-7171), 407 cal BP (WK-7431) and 670–500 cal BP (WK-7262) from one of three freshwater mounds (Guse 2005:110–111; Guse and Majar 2000:34, 36–37). Guse (2005:116) attributed the use of termite mound heat retainer material and paperbark hut decay as the major formation processes for mounds in this region. Ethnographic information indicated high cultural significance is attached to these mounds by local people because of interments and spiritual links to the past (Guse 2005:116; Guse and Majar2000:36).

2.7.2.11 The northern socio-economic context

Brockwell (2006a:47) divided earth mounds that occur in northern Australia into two types, coastal/estuarine and freshwater; and further classified them as multifunctional sites occupied seasonally in a wider settlement system. Both types of mounds tend to be located at the juncture of resource zones close to freshwater features (Brockwell 2006a:54). Coastal/estuarine mounds tend to contain heat retainer, some shell and little else (Brockwell 2006a:54). In contrast, freshwater mounds contain heat retainer material, more stone artefacts and little shell. Northern mounds typically contain termite mound material as heat retainer in contrast to those located in the south-east of the continent which contain lumps of floodplain clay for the same purpose.

Northern mounds appear to be subject to the same formation processes as southern mounds, resulting from the repeated use of earth ovens. Similarly, they were likely used on a seasonal basis according to a wet/dry climatic cycle which resulted in local flooding and an associated abundance of resources similar to the situation within the MDB. However there appears to be significant diversity in the resources cooked in northern mounds, including water birds, mammals, reptiles and plant foods, in contrast to the likely focus on *Typha* spp. in some sub-regions in the south.

2.8 Chapter summary

As previously outlined, this study is on a specific archaeological context within the Calperum floodplain in the South Australian Riverland region. However, the Calperum context is a component of wider cultural, environmental and geographic phenomena as outlined above. The purpose of this chapter has been to review Australian earth mound studies to establish the contextual background for this research. The review has included research from the known precincts where earth mounds have been reported. Whilst differences have been observed in content, type of heat retainer, use of foods processed, morphology and climatic/geographic context; close similarities in landscape placement near water features, dimensions (Figures 2.5, 2.6, 2.14 and 2.15), operation, chronology (Figure 2.4) and seasonality suggest earth mounds are potentially a socio-economic and/or cultural response to similar external influences. The implications of external influences are further explored in Chapter Three.

Chapter Three: Situational Context Associated with Australian Aboriginal Earth Mounds

3.1 Introduction

This chapter seeks to build on data obtained from the literature review of research presented in Chapter Two to establish a situational context for the research conducted at Calperum. This requires a contextual review of Australian earth mound precincts including a synthesis of the relevant archaeology, environmental history, ethnography and ethno-historical accounts of landscapes which contain earth mounds in Australia. As outlined previously, the most significant environments containing earth mounds recorded so far in Australia include some riverine floodplains of the MDB, north-western Cape York, northern coastal areas of the Northern Territory, Western Victoria and the northern Adelaide Plains.

Wetlands, and the resources generally available within their environments, have been a significant factor in human history and evolution since the origins of the *Homo* lineage (Nicholas 1998, 2007a:46–47, b). Archaeological studies have demonstrated many instances of this association, from the Pliocene through the Pleistocene and into the Holocene, in contexts located in Africa, Europe, Asia, North and South America and Australia (Bonsall 1989; Dillehay 1988; Higgs 1961; Jones 1985; Kuehn 1998; Meehan et al. 1985; Walker and Leakey 1993). Ethnographic and archaeological studies of recent and past Aboriginal societies in Australia have highlighted this association and indicate a history of wetland lifeways for millennia prior to the European invasion of this continent (Balme and Beck 1996; Coutts et al. 1979; Jones 1985; Isaacs 1987; Klaver 1998; Martin 2006; Jones et al. 2022; Meehan 1991; Pardoe 1995, 2003; Williams 1988). Palaeo-climatology (e. g., Oz-INTIMATE project 2003), ethnography, ethnohistory (e. g., Berndt and Berndt 1974; Beveridge 1865, 1883, 1889; Eyre 1845; Kirby 1895; McConnel 1953; Mitchell 1838; Moore 1979; Thomson 1939a, b, c; Morrison et al. 2022; Peterson 1973; Sutton 1994) and archaeology (e. g., Brockwell 2006a, b; Klaver 1988; Martin 2006, 2011; Williams 1988) potentially provide important data for the modelling of Australian Aboriginal socio-economic trajectories prior to European contact. These sources provide insights into the contextual use of earth ovens, the developmental processes and operation of earth mounds and the socio-economic significance of these features to Aboriginal societies in both the north and south-east of the Australian continent (Beveridge 1865, 1883, 1889; Brockwell 2006a; Eyre 1845; Kirby 1895; Klaver 1988; Martin 2006; McConnel 1953; Mitchell 1838; Moore 1979; Morrison et al. 2022; Peterson 1973; Sutton 1994; Thomson 1939).

3.2 Ethnographic and ethno-historical sources

A rich and celebrated body of knowledge about Aboriginal cultures and socioeconomic strategies has been recorded by ethnographers including Ronald and Catherine Berndt (1973, 1981,1993), McConnel (1930a, 1930b, 1933, 1934, 1935a, 1935b, 1936a, 1936b, 1937, 1939, 1940, 1953), Meehan (1977, 1982, 1988, 1991), Peterson (1973), Sutton (1978, 1994, 2010) and Thomson (1932, 1939a, 1939b, 1939c). In addition, early contacts with Aboriginal groups in the MDB were detailed by prominent government commissioned explorers and private settlers, including Angas (1847), Sturt (1833), Mitchell (1839), Eyre (1845), Beveridge (1865, 1869, 1883, 1889), Bonney (1884), Gregory and Gregory (1884), Kirby (1895) and Taplin (1875, 1879). However, ethno-historical sources relating to past Aboriginal practices must be carefully evaluated for accuracy and corroborated, where possible, with other sources and by archaeological evidence. Many of the early published accounts were not based on direct observation but relied on information provided by third parties (Balme and Beck 1996:43–45; see also Morrison et al. 2022). Also, in many instances early interpretations reflect biases and attitudes of the time and have little validity in the present (Balme and Beck 1996:45). These concerns are valid when considering this type of information, requiring the use of appropriate caution and cross-referencing.

3.3 The temperate south-eastern context

3.3.1 The Murray Darling Basin (MDB)

Aboriginal peoples of the MDB have been significantly impacted by invasion, colonial dispossession and disease, resulting in dramatic population reductions and the relocation of many survivors into missions and reserves, from the early nineteenth and into the early twentieth centuries (Bonney (1884:123–124; Burke et al. 2016; Butlin 1983; Dowling 2021; Hiscock 2008:12–17). From their study of frontier conflict in the western central Murray River (Figure 2.10), Burke et al. (2016:145) summarised this process as the outcome of:

> Overt violence (the euphemistic 'skirmishes', 'affrays' and 'collisions' of the documentary record), clandestine violence (poisonings, forced removals, sexual exploitation and disease) and structural violence (the compartmentalisation of Aboriginal people through processes of race, governance and labour) became routinised aspects of colonialism, buttressed by structures of power, inequality, dispossession and racism.

The devastating depopulation is demonstrated by the number of ancestors who survived (30 individuals) and had descendants as detailed from a genealogical study of the group associated with the First Peoples of the River Murray and Mallee Region Native Title Claim (Burke et al. 2016:148). This stands in stark contrast to the precontact populations as detailed by Sturt (1849:91–92) from his exploration of the western reaches of the Murray River in 1830, between the Darling/Murray River junction and the Calperum floodplain (Figure 3.1 and 3.2). These included a group of about 600 Aboriginal people encountered at the junction of the Darling and Murray Rivers, then sequentially, parties of about 200 each day. However, ethnographic studies have provided information on socio-economic practices, such as the management of resources and the division of labour within families and clans (Berndt and Berndt 1974:42–43, 1993:77), and the use of material technologies such as canoes, nets, traps and earth ovens (Berndt and Berndt 1974:41, 1993:87–95, 104, 572). As discussed in Chapter 2, ethno-historical accounts were subject to prevailing European racist perspectives of social and cultural superiority laden with stereotypical opinions resulting in damaging consequences for Aboriginal peoples. However, first-hand accounts by explorers and settlers such as Beveridge (1889:32–34), Eyre (1845), Kirby (1885), Mitchell (1839) and Sturt (1833) are useful in providing information on Aboriginal culture, demography and socio-economic circumstances at, or closely following contact with Europeans.

3.3.2 The Calperum study area

The Calperum floodplain area that is the focus of this study is encompassed by the territory of the Erawirung, a sub-grouping of a wider Murray River society (sometimes referred to as Meru) (Tindale 1974:211).[7] The River Murray and Mallee Aboriginal Corporation (RMMAC) is

[7] Other ethno-historical information about cultural boundaries exist in addition to those provided by Tindale (1974). A full synthesis would require a detailed analysis of anthropological and ethno-accounts such as Berndt and Berndt (1993); Curr (1886); Eyre (1845); Horton (1994); Howitt (1904); Taplin (1878) and Tindale (1940), which is beyond the scope of this study.

the representative body which holds native title for the area. Erawirung country extended approximately 10 kilometres north of the northern extent of the Calperum floodplain, extending south and west with a southern boundary 40 kilometres to the south of the Loxton township (Figure 3.1). The wetland resources available within this area included extensive animal and plant (aquatic, and terrestrial) species as well as sources of tool grade stone (Jones 2016; Jones et al. 2017; Thredgold 2017; Thredgold et al. 2017; Tindale 1974:211; Woolmer 1974:21). The Calperum floodplain forms one of a series of contiguous anabranch systems in the South Australian Riverland. The region is characterised by complex networks of seasonal flow paths, oxbows, intermittent lakes and billabongs, back-plain swamps, and expansive floodplains contained within an incised valley up to 9 km wide (Figures 3.1 and 3.2). The geomorphology of the floodplain is based around a series of four alluvial terraces and related landforms that include abandoned channels, meander scrolls, source bordering dunes and lunettes (Westell 2022). To the north the floodplain is bounded by cliff lines and valley slopes that extend from a high mallee and dune-covered plains and to the south by the main channel of the Murray River.

Mounds are a common feature of the archaeological landscape in this area (and the central western Murray more generally) and are most often located on the banks of anabranch creeks, back-plain swamps, billabongs and oxbows (Jones 2016; Jones et al. 2017; Westell and Wood 2014). Riverland mounds (n > 207) display a relatively consistent morphology, being generally circular in plan with diameters of between 3–50 metres (Jones 2016; Jones et al. 2017; Westell and Wood 2014). The mounds are between 0.2–0.7 metres high, and surface observations have revealed that they invariably consist of a fine silt matrix containing burnt clay pellets, mussel shell, ash and charcoal (Jones 2016; Jones et al. 2017; Ross et al. 2019a, b; Westell and Wood 2014:46). Surface surveys have recorded mussel shell fragments in relation to approximately 40 to 50 percent of the mounds recorded in the Riverland floodplains of Calperum, Chowilla and Katarapko (Figures 3.2, 3.5), though often in low quantities (Jones 2016; Jones et al. 2017; Ross et al. 2019a, b; Westell and Wood 2014). Whilst shellfish are known to have been a daily staple in this region (Balme and Hope 1990; Garvey 2017; Mulvaney 1960; Weston et al. 2017), and indeed form extensive midden deposits, the low incidence of this material in mounds potentially indicates either the occasional consumption of mussel around these sites and/or the expedient use of mussel

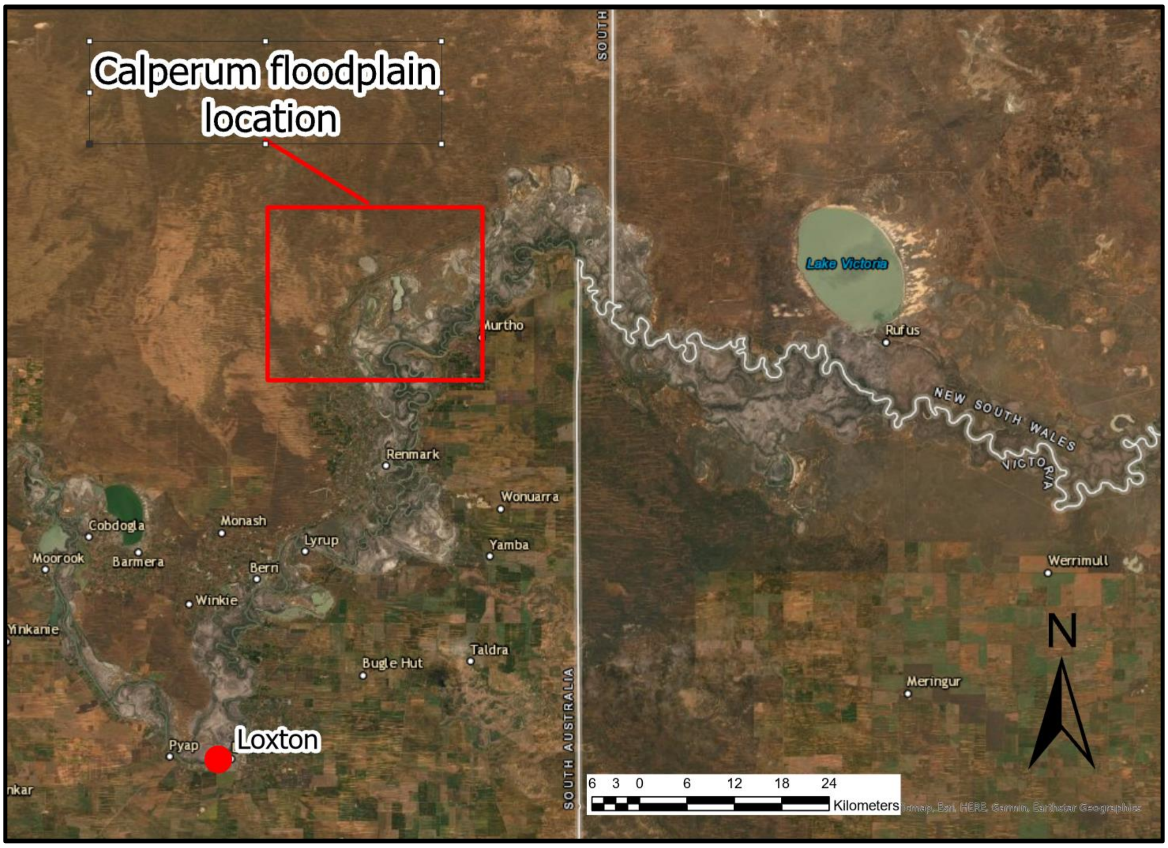


Figure 3.1: A map of the Riverland of South Australia and the Calperum floodplain (left), the South Australian/Victorian border and Lake Victoria region of New South Wales (upper right).

Figure 3.2: Map of the Calperum floodplain.

shell as tools for processing bulrush root and/or other material cooked in these large scale ovens (Angas 1847 Vol. 1:55; Jones 2016:97; Jones et al. 2022; Roberts et al. 2021; Westell and Wood 2014).

Mounds in this region are closely associated with anabranch channels and the margins of lagoons in the more regularly flooded (lower) parts of the floodplain. These environments represent prime habitat for emergent macrophytes such as *Typha* spp. (bulrush) and *Phragmites* spp. (common reed) (Figures 2.7, 2.8) (Jones 2016; Jones et al. 2017; Jones et al. 2022; Westell and Wood 2014:48). As such, prior researchers in the region (as well as further afield in the broader MDB) have suggested that the mounds were primarily used to process *Typha* spp. for food and fibre and not for general habitation (Jones 2016; Jones et al. 2017; Martin 2006, 2011; Westell and Wood 2014:48). This assertion is also supported by ethnohistorical evidence (e. g., Beveridge 1889:32–34; Eyre 1845 2:289–291, 254; Kirby 1895:27–28; Mitchell 1839 2:53, 60, 80–81, 134).

3.3.3 Demography

Limited information from historical sources as well as the impact of diseases previously unknown to Aboriginal peoples make pre-contact MDB population levels, prior to European colonisation, difficult to assess (Pardoe 1990:59). For instance, Bonney (1884:123–124) recorded an epidemic that the 'Bungyarlee' and 'Parkungi' tribes of the Lower Darling River suffered in 1850, which resulted in the regional Aboriginal population suffering a loss of one third of its members in one event, stating that:

> About the year 1850 an epidemic attacked the Bungyarlee and Parkungi tribes, killing about one-third of them. I have been told by some of those who escaped that it came upon them while the country was in fair condition, and there was ample food and water for their wants. The disease affected the legs and quite crippled those attacked (Bonney 1884).

Insights into the economic capacity of floodplain environments, resource utilisation and socio-economic contexts are provided by the analysis of early first-hand accounts. This information, together with archaeological research conducted at Calperum, assists in building a demographic context for this study.

After entering the Murray River from the Murrumbidgee on the 17th of January 1830, the explorer Charles Sturt (1833 2:91–107) recorded an encounter with a group of 83 Aboriginal men, women and children. Later, on the 19th, he noted another group of 150 individuals, and again on the 23rd, a group of 600 people at the junction of the Murray and Darling. As Sturt (1833 2:120–126) travelled further west along the Murray he recorded higher population numbers than previously encountered. After the 24th of January 1830, Sturt (1833 2:135) noted numerous clan groups, distributed in family units, prior to the river changing direction to the south (probably in the vicinity of Reny Island on the Calperum floodplain) (Figure 3.2). The contacts included one group of 270 people and 'detached families', over a considerable distance of the river, derived from one social entity (Sturt 1833 2:135). This likely indicates the presence of social fluidity with the ability to aggregate as necessary, suggesting a localised demographic context and a relatively high population density.

Jones (2016) provided a population estimate of slightly less than two individuals per square kilometre for the Calperum floodplain study area, based on Sturt's observations, previous research (see below) and the local geography. While this is an imprecise estimate, the dimension and productivity of the Calperum and adjacent Chowilla floodplain systems provides some validation (Figures 3.1 and 3.2). It is also comparable with previous estimates for the much poorer resource zone of the Darling River (Pardoe 2003:50) and the narrower floodplain resource zone at Moorundie near Blanchetown (Figures 3.3a, b) (Eyre 1845). Groups of 45 individuals were recorded along the Darling River during summer following higher river levels after winter, dispersing to smaller groups of 13 during other (leaner) times of the year (Allen 1974:313; see also Keen 2004:112–114). For the Murrumbidgee River region, Klaver (1998:282) estimated a similar population density, with an aggregation level of 40 to 60 Aboriginal people during periods of high resource availability and dispersal to groups of 15 at other times. She considered that this reflected seasonal sedentism for periods of up to a month (Klaver 1998:284). In consideration of this evidence, seasonal variation in group organisation is likely to have occurred within the Calperum floodplain. The observations by Sturt (1833) and Eyre (1845) and the evidence cited by Allen (1974), Klaver (1998), Keen (2004) and Pardoe (2003) indicates that Aboriginal groups at Calperum, and in the wider MDB, would have responded to the influence of flood cycles with seasonal sedentism and scheduled social aggregations which coincided with an associated surge of resources. Consequently, the likely period for social and cultural gatherings appears to be during summer following the seasonal flooding cycle and the availability of sufficient resources to support large groups (Klaver 1998:98–102). For instance, Klaver (1998:101) cites Broughton (1847:181) and Kenyon (1930:75) for their accounts of the importance of fish and fish traps (weirs) in supporting local populations along the Murrumbidgee River. Klaver (1998:101) also emphasised the effect of temporary weirs in extending access to aquatic food resources through habitat retention following the receding of seasonal floods. These resources included fish, aquatic and terrestrial plant rhizomes, crustaceans and water birds (Broughton 1847; Gilmore 1986; Townsend 1848).

Ethno-historical evidence combined with previous research suggests that the Calperum floodplain could have potentially supported ten family groups of about ten individuals each prior to the entry of Europeans, resultant frontier conflict and the impact of diseases on regional population levels (Jones 2016). Geographically restricted territories, seasonal availability and distribution of subsistence resources, influenced by the timing and extent of the annual flood regime, likely resulted in a semi-sedentary lifestyle with a high level of group territoriality and limited group mobility (see Pardoe 1995 for a wider analysis of floodplain population dynamics). These groups would have constituted part of a wider social structure comprising several hundred individuals (Eyre 1845 2:372). Such a gathering would occur periodically, during the late summer following annual flooding, for ceremonial, ritual, and social purposes, supported by the seasonal availability of subsistence resources potentially including animals, fish, crustations, birds and carbohydrate rich rhizomes cooked in earth mounds. As supporting evidence of gatherings on the Calperum floodplain, Roberts et al. (2021) cite a historical account of a large intra group gathering at Clover Lake on the Calperum floodplain in 1860:

> Journeying down they found 500 natives assembled, armed with spears and waddies. Two boys stepped out first and fought, the Chowilla boy getting the better of the encounter. The fight then appeared to have become general and perhaps eight or ten were killed. The fight over, the older men called a meeting at which all difficulties were appearently [sic] fixed up. At any rate the tribes separated good friends each taking their own tracks home. (*Murray Pioneer and Australian River Record*, 21 December 1923, p. 2).

3.3.4 Economic resources, procurement strategies and earth mounds

Archaeological and ethnographic research have provided evidence that earth mounds are indicative of intensive economic activity in some riverine and lacustrine environments of the MDB, northern Adelaide floodplain and the wetland systems of the western districts of

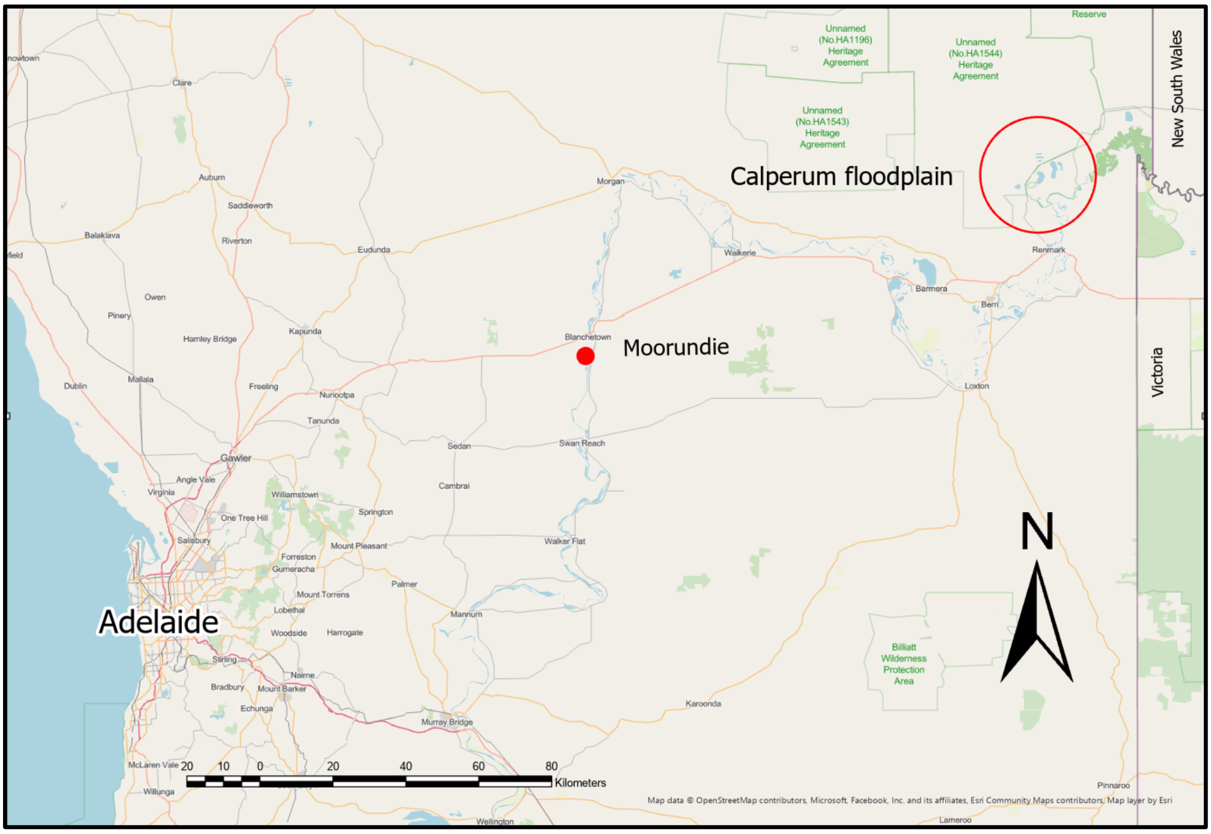


Figure 3.3a: Location of Moorundie and its spatial relationship to Calperum.

Figure 3.3b: Floodplain context of Moorundie near Blanchetown.

Victoria since at least 5000 cal BP (Beveridge 1889; Eyre 1845 2; Jones 2016; Jones et al. 2022; Klaver 1998; Littleton 2013; Martin 2006; Westell and Wood 2014; Williams 1988). Figure 3.4 shows an eroded earth mound located within a wider occupation site (CAPRI17_23) on the western shoreline of Clover Lake at Calperum. A date of 960–805 cal BP (OZX285) was obtained from a fragment of freshwater mussel from the top of this feature (Figure 3.4) (Westell 2022:273). In riverine environments of the MDB such mounds were potentially formed through the intensive operation of earth ovens in response to seasonally abundant plant foods and possibly other food items (Jones 2016; Kenyon 1912:98; Kirby 1895; Mitchell 1839; Martin 2006; Westell and Wood 2014). In part, this study seeks evidence to evaluate this hypothesis.

Earth ovens feature in ethnographic and ethno-historical accounts regarding their construction and use for cooking meat and plant material for carbohydrate and fibre, for instance, Berndt and Berndt (1993:103–107) described the use of the *miramin* method for

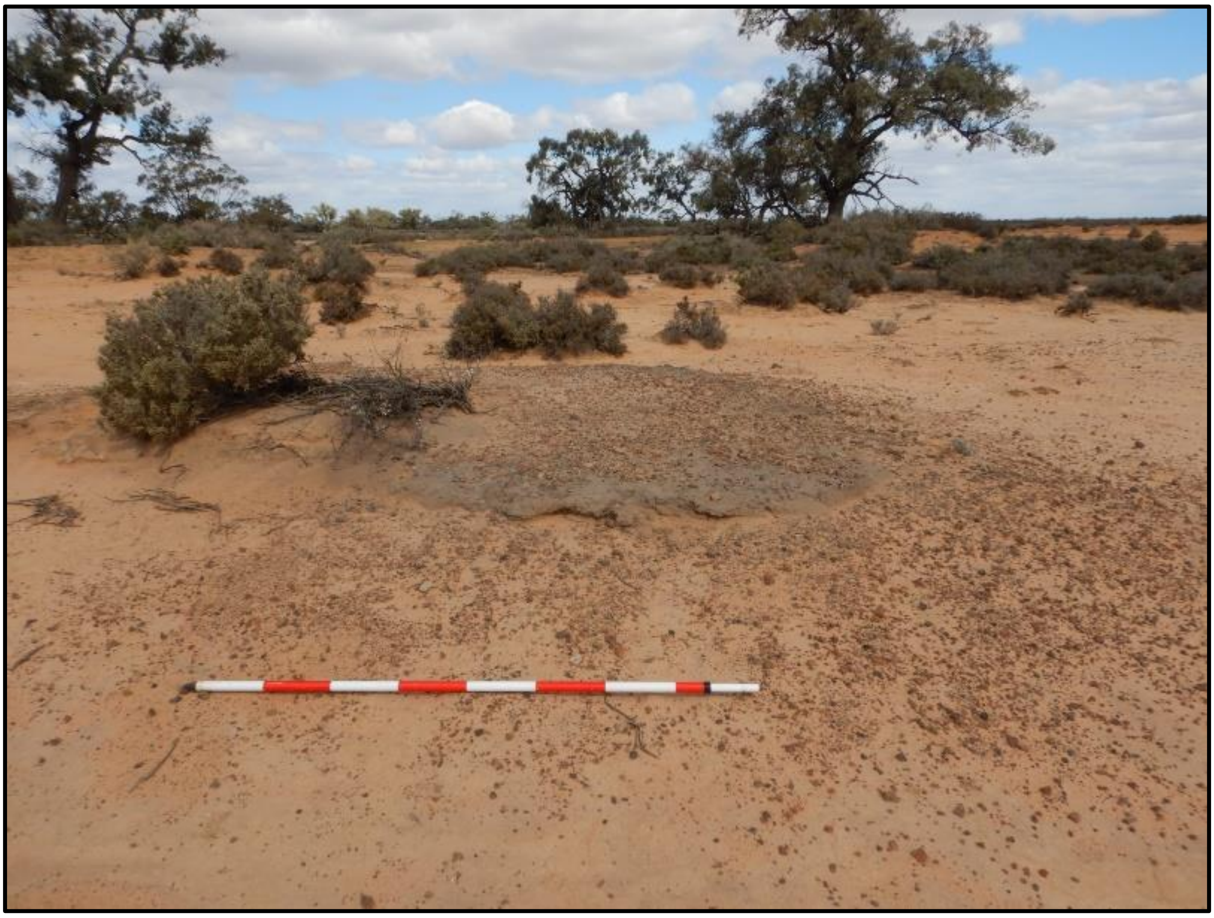


Figure 3.4: An eroded earth mound located in a wider occupation space at Clover Lake on the northern part of the Calperum floodplain. Photo C. Westell 2016.

The cooking of animal and vegetable foods amongst the Aboriginal people of the lower Murray River and Coorong:

> …the meat would be cooked by the *maramin* method. A fire was made in a scooped-out depression and stones were thrown in so that they could be heated to the extent of retaining their heat. When the fire burnt down, the stones were moved about with a wooden poker to form a fairly level base…. Cut *kinyera* grass and *pilbala* grass was strewn over the the stones to keep the meat clean and unburnt….The oven was then covered with *yalkura* or other grass, followed by skins and finally sand so that the heat of the oven would be retained.
>
> [and]
>
> *Manakuri* [*Typha*] roots were steamed in the *maramin* process….pouring water down into the centre to intensify the steaming.

Eyre (1845 2:289–291, 254) also described the process in some detail for the cooking of both animal and plant foods via his observations at Moorundie (Figure 3.3a, b), near Blanchetown, in South Australia:

> The native oven is made by digging a circular hole in the ground, of a size corresponding to the quantity of food to be cooked. It is then lined with stones in the bottom, and a strong fire made over them, so as to heat them thoroughly, and dry the hole. As soon as the stones are judged to be sufficiently hot, the fire is removed, and a few of the stones taken, and put inside the animal to be roasted if it be a large one. A few leaves, or a handful of grass, are then sprinkled over the stones in the bottom of the oven, on which the animal is deposited, generally whole, with hot stones, which had been kept for that purpose, laid upon the top of it. It is covered with grass, or leaves, and then thickly coated over with earth, which effectually prevents the heat from escaping.

[And for]:

> …vegetables and some kinds of fruits, the fire is in the same way removed from the heated stones, but instead of putting on dry grass or leaves, wet grass or water weeds are spread over them. The vegetables tied up in small bundles are piled over this in the central part of the oven, wet grass being placed above them again, dry grass or weeds upon the wet, and earth overall. In putting the earth over the heap, the natives commence around the base, gradually filling it upwards. When about two-thirds covered up all round, they force a strong sharp-pointed stick in three or four different places through the whole mass of grass weeds and vegetables, to the bottom of the oven. Upon withdrawing the stick, water is poured through the holes thus made upon the hissing stones below, the top grass is hastily closed over the apertures and the whole pile as rapidly covered up as possible to keep in the steam.

Beveridge (1889:32–34) noted the construction and use of earth ovens along the River Murray in the Swan Hill region (likely at Nyah Forest [Figure 2.10]) of north-western Victoria:

> Rhizomes, roasted in earth ovens, were eaten all year especially in summer when starch levels were highest. The fibrous matter left after chewing the rhizomes was spun into string to make nets, bags and other essential items of material culture.

See also Beveridge (1883), Gott (1999a) and Krefft (1865) for further observation and comment.

Mitchell (1839 2:53) noted the importance of *balyan* (bulrush-root [*Typha* spp.]) as a staple food for local Aboriginal groups which potentially supported a higher population along the Lachlan River relative to non-riverine landscapes:

> It struck me that this gluten which they call Balyan must be the 'staff of life' to the tribes inhabiting these morasses, where tumuli and other traces of human beings were more abundant than at any part of the Lachlan that I had visited.

Mitchell (1839:80–81, 134) also mentioned the common association of bulrush and the 'lofty ash-hills' (earth oven mounds) used for the preparation of the roots for eating (see also Kirby [1895:27–28] for a similar account for the Swan Hill region of Victoria). Kenyon (1912:102) considered that the mounds of the Murray valley had been derived from the use of earth ovens in contrast to those located in the western districts of Victoria, which were thought to have been occupation sites due to the presence of domestic debris including potential dwelling material. Beveridge (1889:34–35) detailed his observations of the use of mounds as occupation sites during flood periods by Aboriginal people at Swan Hill. Dawson (1881:103) reported, from conversations with Aboriginal people, that mounds were never used for ovens in the western districts of Victoria, potentially indicating that differences in local geomorphic, environmental and climatic conditions dictated different procurement and land use strategies in these contexts.

In an otherwise arid environment, the Murray River was a rich source of subsistence for pre-contact Aboriginal populations in South Australia (Angus 1847 [1969]; Eyre 1845). Terrestrial and aquatic resources were seasonally accessed using technologies derived from local and traded materials including stone for tools and twine for nets (Angas 1847 [1969]:90–94; Eyre 1845 2:251–255, 259–291). The roots of *Typha* spp. supplied both carbohydrate and fibre as a by-product which was used for the manufacture of nets for catching fish, birds, and animals (Angus 1847 [1969]:90; Eyre 1845 2:286–288; Nott 1924; see also Martin 2006). Individual earth ovens and mound features which resulted from their construction and continued use in the same location, were integral and essential to this subsistence activity (Angas 1847 [1969]:99–101).

Eyre (1845 2:291) reported the shared use of a single earth oven between three or four families at Moorundie (Figure 3.3a, b):

> In cooking vegetables, a single oven will suffice for three or four families, each woman receiving the same bundles of food when cooked, which she had put in.

This is of interest in the context of land use and settlement strategies of clan groups. Eyre (1845 2:291) noted that cooking larger animals was the responsibility of male members of the group. Eyre (1845 2:291) further observed that women were the principal gatherers and preparers of vegetable foods within family groups:

> The gathering of vegetable food, and in fact the cooking and preparing of food generally, devolves upon the women, except in the case of an emu or a kangaroo, or some of the larger and more valuable animals, when the men take this duty upon themselves.

This supports Martin's (2006) contention that the procurement of terrestrial tubers and bulrush rhizomes, their cooking in earth ovens, and the mounds which result from this activity, was a social focus for the women of the group, particularly since these were operated on a communal basis (Eyre 1845 2:291). Morrison et al. (2022:18) provided a specific emphasis on the social and niche production aspects of mound construction and use for northern and south-eastern Australia:

> …the existence of an earth oven is not only potentially indicative of the scale of food production, but also, the degree of commensality in the consumption of cooked food. Indeed, the act of sealing uncooked foods within an oven, to be gradually transformed into a sumptuous, subtly flavoured meal to be eaten with others, is a highly symbolic act that illustrates the existence of close kinship ties and potentially other kinds of social and cultural relationships. Thus, earth oven features are potentially indicative of much more than diet and subsistence practices alone and are illustrative of the existence of close or emerging social relationships between those present.

Eyre's (1845 2:244–295) description of the richness of Murray River floodplains, prior to destructive grazing by hard-footed European stock such as cattle and sheep, provides an insight into the likely past productivity of the Calperum floodplain. This is not in evidence today despite the cessation of grazing over 20 years ago. However, the floodplain at Calperum constitutes a prime example of a remnant (but recovering) riverine environment which supported Aboriginal groups along the major river systems of the MDB since their transformation during the terminal Pleistocene (Pardoe 1995; Westell et al. 2020). Eyre (1845 2:252, 372) noted that these environments supported the day-to-day requirements of semi-sedentary populations and provided the resources for seasonal aggregations of up to 600 individuals for ritual and social interactions. This would have been most likely achieved through the deliberate management of the resources surrounding locations designated for a social congregation, thereby preventing damage through over exploitation. Eyre (1845 2:250, 293–295) suggested that the seasonal nature of resource availability linked to the flow patterns of the river ensured that an adequate diet was maintained throughout the year, characterised by seasonal fluctuations and various cultural and socio-economic restrictions as to who and when individuals could consume specific foods (Eyre 1845). However, Webb (1984:165–169) did note the presence of stress indicators from skeletal studies on MDB populations that were probable indicators of nutritional deficiencies, resulting from high population density in the MDB and an association with fluctuations in resource availability, particularly during winter. An outline of the availability resources available to floodplain populations on an annual basis is detailed in Table 3.1 (adapted from Keen 2004:42–44).

3.3.5 Settlement patterns

An archaeological survey of the Chowilla anabranch system (adjacent to Calperum) suggested that the settlement patterns and resource strategies of their pre-contact populations strongly reflected the influence of the annual inundation cycle characteristic of the Murray River (Wood et al. 2005). The Katfish Reach Project Area report (based on the Katarapko – Eckert Creek anabranch system shown in Figure 3.5) identified a cycle which according to Wood and Westell (2010:4) included:

- A yearly contraction of people to higher ground during flood periods, including the floodplain margins and elevated land within the floodplain;
- A settlement focussed on areas immediate to the river or around more permanent water bodies during late summer to winter; and,
- Intense periods of settlement around targeted seasonal resource areas, such as seasonal wetlands.

The Katfish Reach analysis demonstrates that Aboriginal archaeological sites within floodplain environments of the Riverland region occur close to river channels, creeks, lakes and billabongs, rapidly declining with distance from these features (Wood and Westell 2010:7). Archaeological sites were associated with a flood inundation model based on a river flow of 100 gigalitres per day, indicating the influence of flooding on settlement strategies at this level of flow (Wood and Westell 2010:7). Concentrations of larger trees

Figure 3.5: Map of the Katarapko – Eckert Creek anabranch system near Loxton.

and archaeological sites occurred at the margins of landforms associated with previous flooding events, indicating a resource focus for occupation (Wood et al. 2005:68; Wood and Westell 2010:7). The highest number of sites occurred on relic meander plains with higher site densities on and around sandy highland rises bounding floodplain margins, as well as on dunes, levees and lunettes within the floodplain (Wood et al. 2005:66). In addition, mobility was possible in sandy country beyond the floodplain margin and its water resources, because of an underlying layer of clay which contained surface water after rain (Gill 1973:89). This provided accessible water resources in some seasons for 'pool-campers' which allowed access to additional resources, including bush foods and stone suitable for tool making (Gill 1973:89; Tindale 1974:211; Woolmer 1974:21). Seasonal flexibility in resource procurement provided additional space and foraging mobility, and the attenuation of risk of nutritional and social stress associated with a relatively high population density and seasonal variability associated with an arid climate and a flooding regime subject to intermittent drought. Subject to the availability of water, local Aboriginal groups were not

Table 3.1: Food staple availability in the MDB by month, adapted from Keen (2004:42–44; see also Jones et al. 2017). Note: Light grey depicts resource availability, brown indicates seasonal restriction and yellow the annual period of flooding in the MDB.

Vegetable Foods	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Typha spp. (Bulrush)												
Triglochin procera (Water Ribbons)												
Geranium spp. (Native carrot)												
Picris, Cucumis spp.												
Grass seeds												
Panicum decompositum (Native Millet)												
Aristida spp. (Spinifex, var. grasses)												
Masilea drummondii (Nardoo)												
Shrubs												
Portulaca oleracea (Pigweed)												
Artriplex cinerea (Saltbush)												
Chenopodium spp. (Goosefoot)												
Linum marginale Native Flax												
Acacia app. (Mulga)												
Amaranthus spp.												
Pittasporum spp.												
Fruits/leaves												
Portulaca spp.												
Sonchus spp.												
Nitraria spp.												
Disphyma crassifolium (Pigface)												
Tetragonia tetragonioides (Warrigal Cabbage)												
Nasturtium spp.												
Fish/Crustacea	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cherax spp. (Yabby)												
Velesunio ambiguous (Lacustrine mussel)												
Alathyria jacksonii (Riverine mussel)												
Land animals (Various species)												
Kangaroos												
Small mammals												
Birds												
Reptiles												
Flood Period												

totally restricted to the river and its floodplain but also had territorial access to a portion of the hinterland for both subsistence and technology assets (Tindale 1974:211). Ethno-history and the regional archaeological record lend support to the land use and settlement model for the Calperum floodplain outlined above. Whilst noting the indicative nature of Tindale's (1974) tribal boundaries, local groups likely accessed both the floodplain and the nearby hinterland for economic resources, but concentrated effort mainly in the former due to resource richness (Jones 2016; Jones et al. 2017). Eyre (1845 2: 244–295) outlined a semi-sedentary riverine based economy contained within a social and cultural framework of some complexity. Subsistence strategies were flexible and broadly structured; and patently defined by cultural and socio-economic responses to environmental factors such as the annual flooding cycle and the climatic influences acting on it. Flexibility and innovation in resource procurement strategies are a key indicator of, and adaptation to, this environment and a potential example of niche construction which will be explored further in Chapters 4 and 5.

3.4 The tropical northern context

3.4.1 Western Cape York and Arnhem Land

Earth mounds have been recorded in coastal riverine and estuarine floodplain environments in both the northern coastal regions of the Northern Territory and in western Cape York Peninsula (Brockwell 2006a; Brockwell et al. 2017:3; Morrison et al. 2015; Ó Foghlú et al. 2016:11; Ó Foghlú 2017, 2021; Shiner and Morrison 2009; Sutton 1994; Westell and Wood 2014).

At Weipa and Aurukun earth mounds have been located close to the intersection of fresh and saline resource zones and contain burnt termite mound material as a significant component (Figure 3.6). This suggests the repetitive and intensive use of heat retainer technology in specific locations and seasons within the coastal zone of western Cape York Peninsula, and intensive resource exploitation and settlement strategies associated with their development and use. The study by Conyers et al. (2019) indicated that mounds in the Mapoon region were potentially constructed by different processes and purposes than mounds in other regions. Consequently, they are not considered further in this analysis.

Several early ethnographers provided accounts of the material culture and linguistic traditions of the Wik peoples of western Cape York Peninsula. These include McConnel (1930a, 1930b, 1934, 1935a, 1935b, 1936a, 1936b, 1939, 1940, 1945, 1953), Sutton (1978, 1994:31–52), Thomson (1939a, b, c) and Von Sturmer (1978) who provide useful insights into the likely practices and adaptations of closely located populations. The Wik cultural grouping occupied the country between the Archer and Edward rivers inland to Coen in western-central Cape York Peninsula (Figure 3.6). The dominating environmental feature of this country is the division between the narrow, but resource rich, coastal strip and the grass floodplains, wetlands and permanent swamps which extend into the interior (Sutton 1994:31–32). Consequently, a differentiation in lifeways exists within the Wik Aboriginal population, between coastal dwellers and inland groups as a result of variation in local foraging strategies (McConnel 1953; Sutton 1994; Thomson 1939).

McConnel (1953:6–8), during field work on the estuarine Archer, Kendall and Holroyd rivers, outlined a diverse subsistence base exploited by local Aboriginal people. The floodplains of these rivers extend approximately 150 km inland from the west coast of Cape York (Figure 3.7) encompassing an intricate network of channels, wetlands and swamps which provide a significant seasonal habitat for a wide variety of wildlife (McConnel 1953:2). These resources included marine, estuarine, riverine and terrestrial species of mammals, fish, reptiles, molluscs, gastropods, crustaceans, insects and plants, the availability of which were subject to the annual wet-dry tropical (seasonal) cycle which Haynes et al. (1991:xi, 3–4) terms a 'savage alternation'. The annual subsistence cycle, settlement patterns and choices of local people were consequently influenced by relatively large-scale environmental factors associated with the annual weather pattern. Aboriginal people divided this cycle into 5 or 6 seasons which was dominated by a predominantly wet season of monsoonal rain, heat and high humidity, and a 'dry season' with higher daily temperatures and low humidity (McDonald and McAlpine 1991:19–29). Aboriginal people adapted to this extreme environment through mobility, a wide variety of seasonal animal and plant resources and included the use of ant bed ground ovens (McConnel 1953:6–8). Thomson (1939a:221–222) also documented the use of earth ovens for both animal and vegetable foods in the salt-water creek environments of the coastal plains of western Cape York:

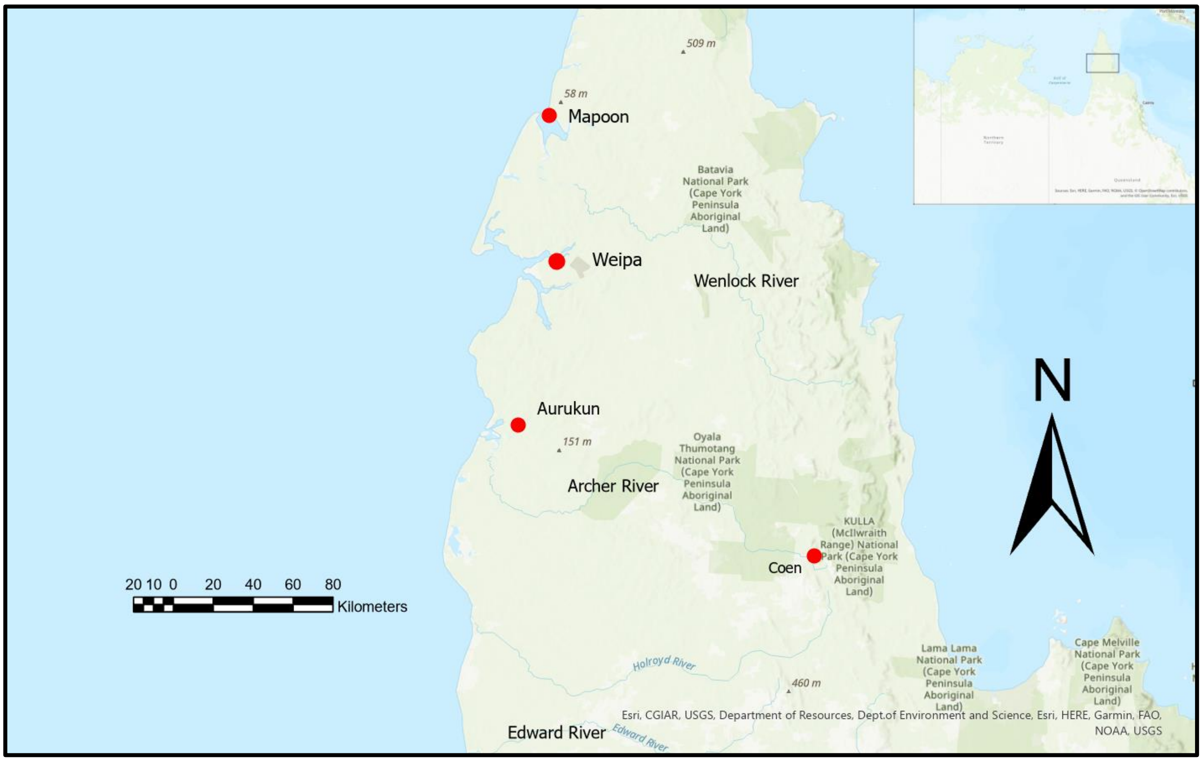


Figure 3.6: Location of major northern Cape York rivers and townships.

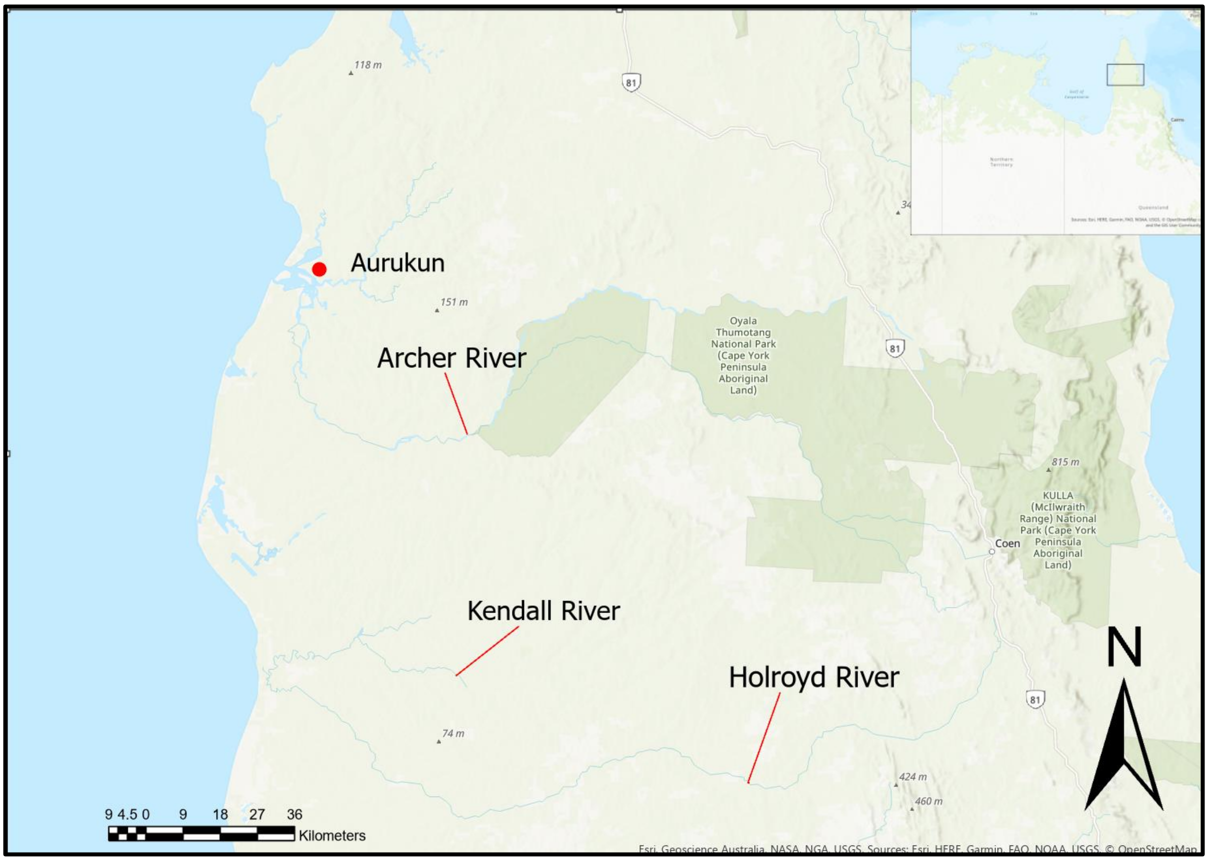


Figure 3.7: Map showing locations of the Archer, Kendell and Holroyd Rivers in northern Cape York.

> …there was an ant bed 'oven' called pia by the Wik Monkan—which is employed by the people through Cape York Peninsula and over a large part of tropical Northern Australia, for the cooking of larger game, such as kangaroos, wallabies and emu, as well as for much of the vegetable food.

Thomson (1939a:221) further indicated the potential longevity of oven sites in the landscape due to the soil and ash accumulations which are a result of their use. Sutton (1994:42, 44) noted the preferred use of termite mound pieces as heat retainer material by coastal groups, in this context, as well as less preferred material such as lumps of shell grit and swamp mud, although he indicated that stone was possibly used as heat retainer in inland areas where available. The cooking process was also ideally subject to the availability of sand for easy digging and sealing the oven, as well as supplies of paperbark for wrapping the food (Sutton 1994:44). Sutton (1994:44) cites the availability of ant bed material and paperbark trees as criteria for the selection of optimal camp sites. Earth oven sites were near but not co-located with overnight and base camps because of landscape hygiene issues associated with the accumulation of offal, skin, feathers and bone (Sutton 1994:44). It must be noted that despite the wide-spread use of earth ovens in Cape York Peninsula no earth mounds have been reported other than in a restricted area of the coast at Weipa and Aurukun at this time.

3.4.2 Demography

In 1930, McConnel (1930a:99, 1930b:181) estimated the population of coastal Wik people to be between 200–300 individuals, down from 1500–2000 prior to the introduction of diseases previously unknown to local populations. McConnel (1930b) estimated the population density of the inland Wik people to be one person per 5.1 km^2. Sutton (1978:90) estimated a population density, within the coastal sector, of I person per 5.9 km^2, based on clan areas and an average clan size of 20 people, prior to contact and suggested a much lower density for inland populations because of lower resource availability. Tutchener (2018) argued that neither McConnel nor Thomson recorded clan numbers in their early research and precluded the possibility of any real accuracy in estimating past population densities for the Kuuku I'yu people in central Cape York, particularly in respect of the prior impact of disease (see also Von Sturmer 1978:75). However, Tutchener (2018:85) does conclude that an approximation between the estimations of Chase (1980b:157) and McConnel (1930b) of 1 person per 7–9 $km^{2,}$ is a reasonable working compromise for inland populations. However, at the local level, this would be heavily reliant on the resource productivity of individual eco-zones.

3.4.3 Economic resources, practices and earth mounds

Several researchers have noted a seasonal pattern to the subsistence economy in western Cape York Peninsula (Chase and Sutton 1981; McConnel 1953; Sutton 1994:37; Von Sturmer 1978). Table 3.2 details common vegetable plant food species harvested by women when in season. Sutton (1994:41) observed that inland populations accessed fewer vegetable staples and vegetable foods in general than coastal dwellers. Both coastal and inland populations accessed fish and larger animals such as kangaroos, wallabies, possums and bandicoots when available, with the latter also focused on freshwater fish, shellfish and reptiles. (Sutton 1994:41).

Ethnographic and archaeological research in Arnhem Land and western Cape York, have identified a close association of earth mounds with seasonally productive wetlands (Baker 1981; Bourke 2000, 2004; Brockwell and Aplin 2020; Brockwell et al. 2017:3; Brockwell 2006a; Guse 2005; Guse and Majar 2000; Meehan 1988, 1991; Shiner and Morrison 2009; Ó Foghlú et al. 2016:11; Ó Foghlú 2017; Peterson 1973; Roberts 1991; Thomson 1939a:220–221: Woodroofe et al.1988). Peterson's (1973) ethnographic research at the Arafura Swamp in Arnhem land, Northern Territory, provided a subsistence and settlement model for groups exploiting resources in the Australian tropics. He outlined a sequential model of plant food availability by season and location (Table 3.3) and noted that animal foods were less localised but predictable from local knowledge accrued over time (Table 3.4) (Peterson 1973:182). Freshwater fish are most easily obtained immediately after the end of the wet season when the water is extensive and shallow, as well as later in the season when rivers contract to isolated pools (Peterson 1973:182).

Tables 3.3 and 3.4 indicate the concentration of resource availability at the terminal wet and early dry seasons of both animal and plant foods at the Arafura swamp in Arnhem land, Northern Territory. Vegetable foods constitute the basis of the diet because of greater certainty of location and yield in comparison with the vagaries of the hunt which is consequently less certain of delivering a regular and reliable outcome (Peterson 1973:183–184). Peterson (1973:184) emphasises the importance attached to a balanced diet by local

Table 3.2: Common vegetable foods prior to European contact in western Cape York Peninsula (adapted from Sutton 1994:37–38).

Botanical name	Common name	Portion eaten
Ficus spp.	Fig	Fruit
Livistona spp.	Palm	Core
Tacca leontopetaloides	Arrowroot	Tuber
Dioscorea sativa	Round Yam	Tuber
Dioscorea transversa	Long Yam	Tuber
Cayratia spp.	-	Tuber
Nymphaea lotus	Lotus Lily	Stems, roots, leaves
Nymphaea gigantea	Water Lily	Stems, roots, leaves
Elocharis dulcis	Water Chestnuts	Corms
Avicennia morina	Grey Mangrove	Fruit
Bruguiera gymnorhiza	Black Mangrove	Fruit
Parinari nonda	Nonda Apple	Fruit
Eugenia spp.	-	Fruit
Mallotus polyadenus	Black Cherry (Green Kamala)	Fruit
Mimusops elengi	Red Fruit	Fruit
Planchonia careya	Wild Mango	Fruit
Sterculia quadrifida	Monkey Nut	Nuts

Table 3.3: A seasonal representation of plant food availability at the Arafura Swamp which indicates the resource pulse at the wet-dry transition (adapted from Peterson 1973:181–182).

Month	Season	Focus	Plant Staples	Available species	Availability over time
Sept. to Dec.	Wet	Freshwater complex	Aquatic roots and tubers	14	Swamp staples reduce
Jan. to Mar.	Wet	Monsoon rainforest	Rainforest fruits and yams	12	Becoming abundant
April to Aug.	Dry	Fan delta	Yams	21	Increasingly lean after the wet

Table 3.4: A seasonal representation of animal food availability at the Arafura Swamp (adapted from Peterson 1973:181–183).

Resource	Month											
Resource	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Marsupials	■	■	■	■	■							■
Honey		■	■	■	■	■						
Fish			■	■	■	■	■	■	■	■	■	
Turtle eggs				■	■							
Amphib./reptiles				■	■	■	■	■	■	■		
Birds							■	■	■	■	■	
File snakes (*A. javanicus*)										■	■	

Aboriginal people and notes the imbalances which do occur due to seasonal variations (see also, Thomson 1939b). Harris (1975) recorded plant usage along the Claudie and Lockhart Rivers in eastern Cape York Peninsula. These lay east of the upper reaches of the Wenlock and Pascoe Rivers in relative proximity and demonstrate similar open canopy woodland environments (Tutchener 2018:89). Harris (1975) lists important plant species likely to have been of significance to the Kuuku I'yu people (see Table 3.5).

3.4.4 Settlement patterns

Von Sturmer (1978:533) noted that hinterland estates, immediately inland of those of the western Cape York coast (Figures 3.6 and 3.7), are larger in area than coastal examples, due to lower resource availability, and consequently exhibit a lower population density. Water is available even during the dry season though spatially dispersed leading to group dispersal and significantly different social relationships than apparent within and between coastal groups (Von Sturmer 1978:534–535). Specifically, group dispersion, low population density and a large choice of potential camp sites allowed for the minimisation of conflict and a less hierarchical society not characterised by the political ascendancy of 'big men' (Von Sturmer 1978:536). Von Sturmer (1978:530–531) confidently argued that inland group mobility was constrained by seasonal flooding and posited a relatively stable annual resource cycle despite being unable to comment on wet season subsistence strategies through lack of knowledge. Within the floodplain environments of the study area located in western-central Cape York Peninsula, the seasonal concentration of resources at the transition from the wet to the dry season provides a likely rationale for the location and development of occupation sites (base camps). Such sites were located to access resources on the edge of wetlands, as demonstrated in Arnhem Land in the Northern Territory (Peterson 1973:184).

Peterson (1973:184–186) detailed an annual settlement cycle in Arnhem Land, where base camp location was primarily dictated by the availability of plant foods and fresh water and indicated some variation in timing due to seasonal factors (Table 3.6). As would be expected this suggests a degree of fluidity in the targeting of resources. In this case earth mounds were in the vicinity of a base camp location sited on a sandy fan delta in a well-drained area near water. They were utilised at the transitional wet-dry period where mounds provided refuge from flooding and continued access to resources (Peterson 1973:186). This is analogous to the settlement and land use response to the hydrological cycle in the MDB

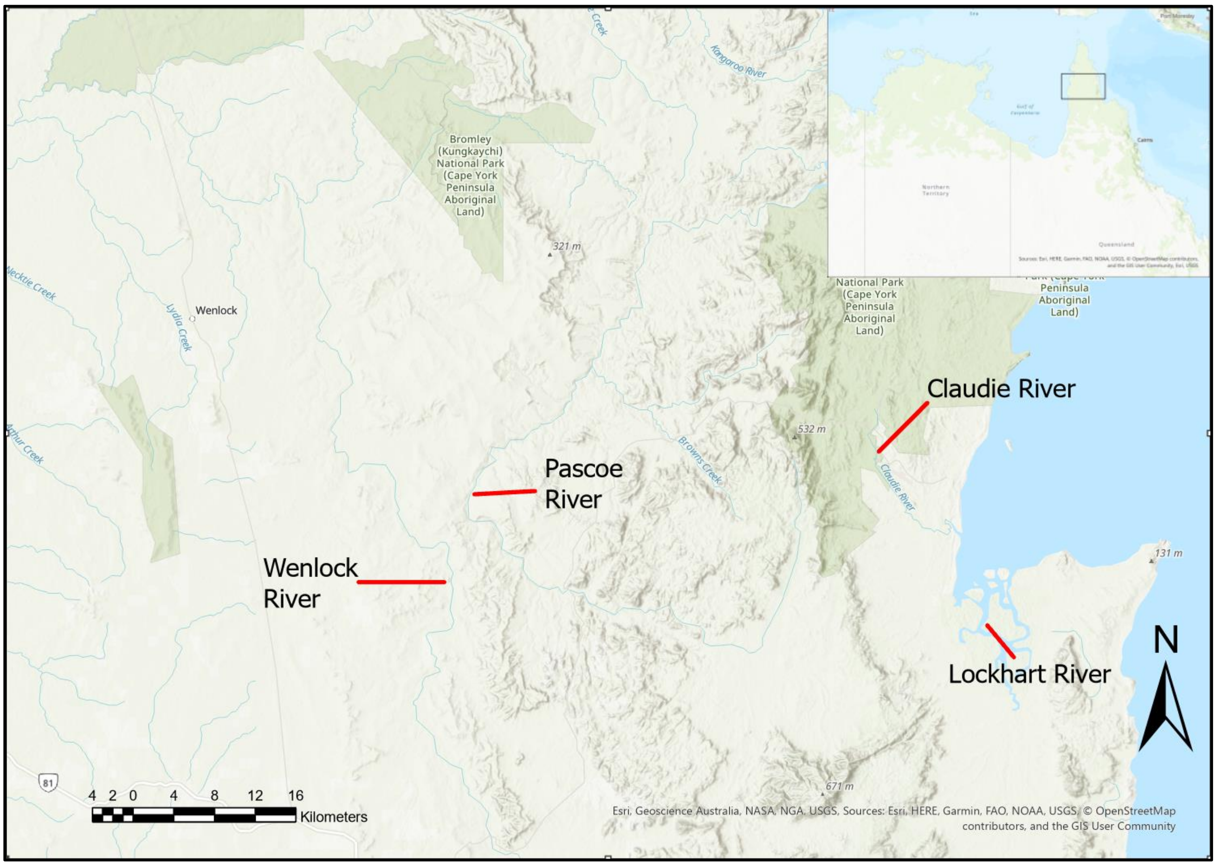


Figure 3.8: River systems of eastern Cape York mentioned in the text.

Table 3.5: Woodland and rainforest plant species likely to be important to the Kuuku I'yu people (adapted from Harris 1975, see also Tutchener 2018).

Botanical name	Common name/type	Portion eaten	Comment
Cycas media	Cycad	Seeds	Toxic (preparation required)
Livistonia humilis	Palm	Core	Fall back early wet
Ptychosperma macarthurii	Palm	Core	Fall back early wet
Ficus spp.	Fig	Fruit	
Eleaeocarpus grandis	Blue quandong	Fruit	
Aleurites moluccana	Candle nut	Nut	
Musa acuminata	Wild banana	Fruit	Source of carbohydrate
Alpinia caerulea	Wild ginger	Tuber and fruit	
Archontophoenix alexandrae	Palm	Fruit	Starch
Gulubia costata	Palm	fruit	Starch

(particularly in the central Murray region from the South Australian Riverland east to Echuca in Victoria), as discussed briefly in Chapter 3 and outlined in more detail above (see Beveridge 1869: clxxxviii; Coutts et al. 1979). This suggests the intensive use of heat retainer cooking for the preparation of a seasonal flush of resources and consequently the useful physical development of mounds as living spaces, in some areas through the build-up of sediment. In the MDB such elevated occupation platforms potentially provided refuge from flooding and

Table 3.6: Annual settlement cycle for a group exploiting resources at the Arafura Swamp over the period 1965–68 (Peterson 1973:185).

Location	1965–66	1966–67	1967–68	Resource
Tall open forest	Late December-April	January-April	December-April	Forrest fruits, marsupials and fish
Sandy fan delta	Late April-July	May-August, December	Late April-September	Fish, yams, marsupials, roots, turtles and eggs
Stream and swamp	August-December	September-November	October-December	Lilly roots, file snakes and fish

continued access to wetland resources (Coutts 1976, 1979). Potentially this is a cultural adaptation which has likely arisen in response to similar environmental conditions in at least four separate climatic regions in Australia, including the MDB, Arnhem Land, the northern Adelaide Plains and western Victoria from the mid Holocene (Coutts et al. 1976, 1979; Jones et al. 2017; Littleton 2013; Peterson 1973; Westell and Wood 2014; Williams 1988:218–221) and which could also possibly be the case in western Cape York Peninsula.

3.5 Mid to late Holocene chronology of Australian climate variation

Australian climate is dominated by two key climate systems, the tropical northwest monsoon, which impacts the north of the continent during the southern hemisphere summer, and the westerly weather patterns of the Southern Ocean (Williams et al. 2015a). In addition to these main influences, other cyclical phenomena also affect rainfall patterns across Australia. These include the El Niño Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), the Interdecadal Pacific Oscillation (IPO), the Southern Annular Mode (SAM) and seasonal movement of the Inter-Tropical Convergence Zone (ITCZ), each of which can affect rainfall patterns alone, or in conjunction with each other (Risbey et al. 2009; see also Williams et al. [2015a] for a detailed outline of these phenomena). Within the complexity imposed by the climatic systems outlined above, major periods of climatic change have also been noted, including the MHCO, the Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA) due possibly to the interaction of the mechanisms outlined and/or wider influences such as solar activity. The culmination of recent palaeo-climatic research (Oz-

INTIMATE) for the Australian region has provided a continental-scale climate synthesis for the Australian region which covers the last 35,000 years (Barrows et al. 2013; Petherick et al. 2013; Reeves et al. 2013; Turney et al. 2006; Williams et al. 2015a). See Table 3.7 for key data sets for mound precincts. The results of this research suggest that the climatic systems evident from about 6000 cal BP to the present, evolved from the systems active at the Pleistocene/Holocene transition (Petherick et al. 2013; Williams et al. 2015a).

Hesse et al. (2004) argued that climate ameliorated from about 15,000 to 13,000 cal BP across the Australian continent during the Pleistocene-Holocene transition, with evidence of local differences in the timing of hydrological changes. Precipitation and runoff increased in the early Holocene with a general trend to aridification in the north from about 5000 cal BP (Fitzsimmons 2013:92; Petherick et al. 2013). Lakes in northern and central Australia peaked around 6000 cal BP, followed by drier conditions in the north from about 5500 cal BP (Hesse 2004:99). Speleothem data from Yudnamutana in the Flinders Ranges indicated variable precipitation from about 11,500 to 8000 cal BP, with higher precipitation between 7000 and 6000 cal BP (Quigley et al. 2010). An analysis of a tropical lowland pollen record from Groote Island by Shulmeister and Lees (1995:12), suggested that effective precipitation (EP) peaked at about 4000 cal BP, followed by an arid phase which extended to about 2000 cal BP, with recovery from that time.

Luly et al. (2006:1091) identified significant changes at Three-Quarter Mile Lake in eastern Cape York Peninsula which indicated higher effective rainfall from about 5000 cal BP with a change from *Typha* dominated lake margins to *Cyperaceae*, water lilies and ferns. From their investigation of the Big Willum Swamp, in western Cape York, near Weipa, North Queensland, Stevenson et al. (2015:27) found five environmental phases represented in lake-bed cores spanning the mid to late Holocene. This indicated a variable moist habitat to about 7000 cal BP; the initiation of swamp conditions from about 7000 cal BP; drier conditions, lake contraction and a decrease in sedimentation from about 5000 to 2200 cal BP; a perennial water body after 2200 cal BP and then essentially modern conditions thereafter.

Higher precipitation levels evident on the east coast of Cape York, in contrast to the western coast (Stevenson et al. 2015) and Arnhem Land (Fitzsimmons 2013:92; Hesse 2004:99), were attributed to easterly trade-winds during the winter dry season thereby emphasising the influence of geographic and environmental variation on local climate conditions (Luly et al. 2006:1092). As noted above, earth mounds have not yet been reported on the central and

Table 3.7: Key regional climatic datasets by mound precinct including author's name and reference.

Region	References
General	Williams et al. (2010) Williams et al. (2015)
Western Cape York Peninsula	Stevenson et al. (2015)
Eastern Cape York Peninsula	Haberle and David (2004) Luly et al. (2006)
Arnhem Land	Hesse et al. (2004) Shulmeister and Lees (1995)
Central Australia	Quigley et al. (2010)
South-eastern Australia	Bowler and Hamada (1971) Fitzsimmons et al. (2013) Fitzsimmons and Barrows (2010) Gell et al. (2005) Gingele et al. (2004, 2007) Hesse et al. (2004) Jones et al. (1998) Petherick et al. (2013) Shulmeister and Lees (1995)

eastern areas of Cape York, possibly supporting the influence of climatic factors on resource procurement systems as key to their origin and use. A decrease in runoff from about 15,000 to 13,000 cal BP in the south-east of the continent was variously attributed to moisture uptake by returning vegetation, decreased snow melt and the influence of peri-glaciated ground (Fitzsimmons 2013:92; Hesse et al. 2004:99). Generally wetter conditions prevailed from about 7000 to 5000 cal BP in south-western Victoria as indicated by high lake levels (Bowler and Hamada 1971; Jones et al. 1998; Fitzsimmons 2013; Fitzsimmons and Barrows 2010), followed by lower discharge from MDB rivers and a trend towards aridity after 5000 cal BP (Gingele et al. 2004, 2007; Petherick et al. 2013:69–70; Shulmeister and Lees 1995). A study of diatoms and macrophyte pollen from coring undertaken at Tareena Billabong, at the eastern edge of the Chowilla floodplain (adjacent to Calperum) in the Riverland of South Australia (Figures 2.11 and 6.1a), suggests Tareena Billabong was a permanent fresh lagoon isolated from the main channel at about 5000 cal BP with reconnection occurring after 3800 cal BP with the likely onset of wet-dry cycles and increased variability from that time (Gell et al. 2005:450; Tibby et al. 2006:206, 264).

The generally favourable conditions during the transition from the LGM until about 5000 cal BP (end of the mid Holocene optimum) has been posited as a time of increased biomass productivity and sustained growth in population in north Queensland (Haberle and David 2004:177). As climatic variability and aridity increased, available resources likely decreased, leading to impacts on group size and diet choices. The summed probability distribution (SPD) analysis by Williams (2013:6) potentially suggests a hiatus in economic activity evident around 5000 to 4500 cal BP that coincides with the earliest earth mound dates and is a possible indication of economic activity trends at the time. The debated accuracy of SPD analysis as a proxy for population trends is noted, however the underlying radiocarbon data are robust, and considered relevant to this study. Thus, the emergence of earth mounds is potentially an earlier response to environmental variability than an intensification of seed grinding and the exploitation of toxic plants. Haberle and David (2004:177) cited evidence of the latter by 3000 cal BP in the north Queensland region as evidence for a broadening of diet, positing a possible combination of climatic change and social factors as causation (see also David 2000; McNiven 1999:158–159). A resumption in the rate of population growth identified by Williams et al. (2015a:52), after about 3800 cal BP, was potentially due to a reorganisation of resource procurement strategies in response to the onset of ENSO induced climatic variability from about 4500 cal BP. See Table 3.8 for a summary of climate patterns in northern and south eastern Australia from the mid Holocene.

ENSO related climatic variability, in the Australian region, from about 5000 cal BP coincides with the apparently simultaneous appearance of earth mounds in both northern and south-eastern regions of Australia as indicated by available ^{14}C data (Figure 3.9). The correlation of the apparent emergence of earth mounds over two widely separated regions at about the same time is intriguing, and potentially indicative of a relationship between wider environmental factors, resource procurement and socio-economic transitions at both local and regional levels. Such correlation is key to the identification of potential influences behind the introduction of previously marginal foods (which are often subject to more complex preparation requirements) and the potential broadening of Aboriginal diets at this time.

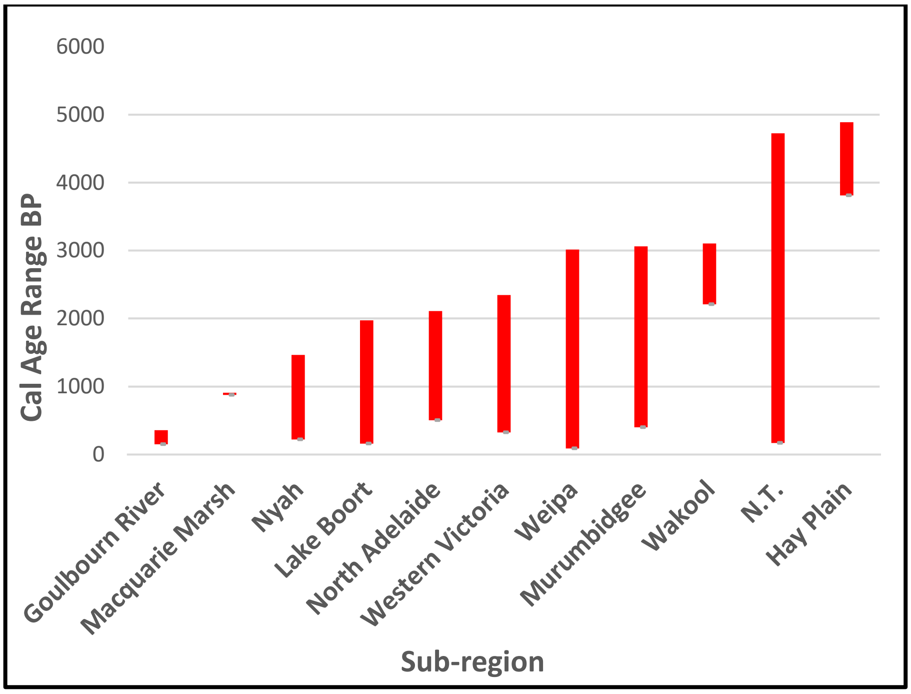


Figure 3.9: Calibrated radiocarbon age range by sub-region in the MDB, Northern Territory and Weipa regions (derived from Balme and Beck 1996; Berryman and Frankel 1984; Brockwell 2001b, 2005, 2006 a, b; Brockwell & Ackermann, 2007; Brockwell et al. 2009, 2017; Coutts et al. 1977; Godfrey et al. 1996; Johnson 2004; Klaver 1998; Littleton 2013; Martin 2006; Westell and Wood 2014; Williams 1988). See also Figure 2.1 for a spatial indication of the major mound precincts and the number of radiocarbon ages available from each region.

Table 3.8: Chronology of significant climate shifts within the Australian region from the mid Holocene to 500 cal BP.

Chronology	Comment
~5000 cal BP	Drying trend following the Last Glacial Maximum (Bowler and Hamada 1971; Fitzsimmons 2013; Fitzsimmons and Barrows 2010; Gingele et al. 2004, 2007; Jones et al. 1998; Petherick et al. 2013:69—70; Shulmeister and Lees 1995)
3800 cal BP	Onset of ENSO variability (Gell et al. 2005; Tibby et al. 2006; Williams et al. 2015a)
2500—2200 cal BP	ENSO (Shulmeister and Lees 1995)
2200—1800 cal BP	Transition to wetter conditions (Stevenson et al. 2015)
1200—800 cal BP	Period associated with Medieval Climate Anomaly, wetter conditions, high amplitude storm activity ~1300—1150 cal BP (Williams et al. 2010)
500 cal BP	Commencement of Little Ice Age at 500 cal BP (Williams et al. 2010)

3.6 A situational synthesis

The review of the work of ethnographic, archaeological and palaeo-climate researchers and ethnohistorical information from early observers detailed here, suggests a nexus of external influences, adaptation and changes in procurement strategies across a number of widely separated and discrete wetland precincts in Australia at about the same time. Traditional subsistence strategies adopted by groups within these precincts were based on a wide variety of plant, animal and aquatic resources according to seasonal availability. However, differences noted by McConnel (1953), Sutton (1994) and Thomson (1939a) between the subsistence strategies of coastal and inland dwellers in northern Cape York are a potential example of the influence of resource availability and seasonal abundance in driving differences in local procurement strategies and in the implementation of innovation within adjacent populations.

The concurrent development of earth mounds derived from the continued use of an earth oven in the one locality, in some cases over hundreds of years. Their location near prime aquatic resource habitats and the presence of heat retainer material are the dual criteria which relates otherwise unconnected precincts within and between these regions. The use of earth ovens by Aboriginal peoples for cooking both animal and plant resources has been widely acknowledged as an integral technology amongst Aboriginal groups since at least 34,000 cal BP (Whitau et al. 2018) and possibly from about 59,000 cal BP (Clarkson et al. 2017; Florin et al. 2020). The enduring history of earth oven use and the relatively sudden emergence of enduring, circular, mounded remnant deposits of earth oven components in the archaeological record at about 5000 cal BP constitutes a significant variation to traditional practices and clearly signals socio-economic and cultural changes from that time.

Hiscock (1994:267–292) examined technological responses to existential risk due to inadequate resource provisioning of mid to late Holocene Australian Aboriginal populations in relation to the colonisation of previously uninhabited or under-utilised regions and climatic variability. Hiscock's discussion focussed on stone artefacts (points, backed blades and tulas), new methods of use and design, changes to the subsistence base of highly mobile groups and the chronological association of such change with climatic and environmental instability (Hiscock 2008:158, 1994:267–292). Risk management through the development and maintenance of stone artefacts, repurposing existing technologies and the exploitation of marginal subsistence resources can potentially be considered as an adaptive response to externally driven change which will be considered in the exploration of theoretical frameworks in Chapters 4 and 5. The implementation of innovation in the repurposing, redesign and/or the intensification of prior techniques and practices, potentially enabled greater productivity in resource exploitation to address risk. Such risk was associated with entry or re-entry to specific under-utilised regions, climatic variability and demographic pressure as population trajectories developed from the end of the LGM. Potential technologies and/or techniques include grinding of seeds and tubers, replanting vegetative portions of plants for regrowing, the intensive exploitation of eels, toxin removal in nuts and tubers, storage of food surpluses and heat retainer cooking, all of which widen the diet choices available. Such practices were arguably part of the human economic repertoire for millennia, both in Australia and globally (Black and Thoms 2014; Clarkson et al. 2017; Salazar et al. 2012; Thoms 2015; Whitau et al. 2018). Such technologies were probably used or repurposed as necessary in the continual struggle for survival and not necessarily visible in the archaeological record until relatively recently because of environmental variability, taphonomic processes and/or previously low levels of intensity in the use of individual landscapes.

Ulm (2006:256) emphasised the importance of regional studies and the development of an understanding of 'the complexity of temporal and spatial diversity' thereby 'disentangling' local diversity from 'amorphous' continental narratives which fail to provide a context for regional cultural and historical trajectories (see also Frankel 1993:31). From about 5000 cal BP some populations in tropical and temperate floodplain regions in Australia demonstrate similarities in the application of innovation to access high, but seasonal, resource productivity which supported a potentially high population density capable of seasonal aggregations. Under this hypothesis, a combination of local geomorphic and climatic factors produced variability in patterns of seasonal flooding and in the productivity of floodplain environments, acting as key influences on the implementation of technical and cultural innovations resulting in new socio-economic behaviours. New cultural and economic niches resulted from this interplay of environmental variability, human ingenuity, management and socio-economic re-organisation. Thereby providing new subsistence opportunities and the necessary material requirements for local populations through a seasonally determined procurement strategy.

Earth mounds are potentially one example of a change in subsistence procurement and are significant remnant artefacts of Aboriginal use of riverine landscapes within these localities. The re-purposing and intensive use of heat-retainer technology in specific locations and the development of earth mounds is potentially indicative of innovation (as a process) influencing a transition in social organisation and resource procurement through an expansion of diet choice. The emergence of this innovation at about 4900 cal BP in both northern and south-eastern Australia may reflect external influences, or alternatively a continuing trajectory of intensification and development of broad-spectrum diets from the terminal Pleistocene, albeit at different rates, in different ways and in different places.

3.7 Chapter summary

This chapter has reviewed the situational characteristics of the major Australian earth mound precincts with an emphasis on the south-eastern region and the Calperum floodplain as the major component of this study. Each has been examined and compared from a number of perspectives, including brief overviews of history, geomorphology, demography, economic resources and procurement strategies. Differences and similarities have been considered and highlighted to inform later discussions.

Chapter Four: Theory and Context

4.1 Introduction

The consideration of theoretical frameworks for this research necessarily involves an acknowledgement of the historical context within which the lifeways of Indigenous people have been studied in the past and which continues to resonate to the present. The Māori scholar, Smith (1999:86–87) has argued that:

> Indigenous peoples have been, in many ways, oppressed by theory. Any consideration of the ways our origins have been examined, our histories recounted, our arts analyzed, our cultures dissected, measured, torn apart and distorted back to us will suggest that theories have not looked sympathetically or ethically at us.

However, Smith (1999:87) also states:

> I am arguing that theory at its simplest level is important for Indigenous people. At the very least it helps make sense of reality. It enables us to make assumptions and predictions about the world in which we live...If it is a good theory it also allows for new ideas and ways of looking at things to be incorporated constantly, without the need to search constantly for new theories.

Smith (1999:89) identified the need to consider carefully and critique methodologies and methods of research before their application. This can be achieved through appropriate consultation and discussion, opportunities for co-authorship and endorsement through formal application processes as required under heritage protection legislation and through due consideration and ethical assessment. These criteria have been foremost in the planning and execution of this research, including collaboration with the Aboriginal community represented by the River Murray and Mallee Aboriginal Corporation, the Flinders University Ethics Committee and the Aboriginal Affairs and Reconciliation Division of the South Australian State Government (see also Chapter Six).

4.2 Intention

In this and the next chapter I aim to contextualise the research associated with Aboriginal earth mounds located in riverine wetlands and floodplains in Australia and assess theoretical aspects within a global overview. The potential relationship between the introduction of 'broad spectrum diets' in Australia and the trajectory of socio-economic changes during the mid Holocene will also be explored. In the first instance this requires an examination of the relevant general and mid-range theoretical frameworks which have been formulated for the analysis of 'hunter-gatherer' socio-economic strategies on a global basis. The review will seek to identify, review and outline relevant theoretical frameworks, and the theoretical and methodological opportunities which may assist in the development of new perspectives in this study. This will then inform an evaluation of Australian archaeological research associated with earth mounds and the relevant wetland/floodplain environments outlined in Chapter 3. The analysis will aim to provide a conceptual framework for the consideration of the emergence of earth mounds, socio-economic trajectories in different regions of Australia and the introduction of BSD during the climatic and environmental transition from the terminal Pleistocene.

4.3 Theoretical background

4.3.1 Overview

Hunting, fishing and gathering have been the dominant subsistence strategies in human history, under-pinning systems of social and economic organisation until the terminal Pleistocene and the emergence of horticulture, pastoralism and agriculture in western Asia after the end of the Last Glacial Maximum (LGM) (Bellwood 2022; Bettinger 1991:1; Bettinger et al. 2015; Kelly 1995:1).

Since its origin as an academic field of study, research on hunter-gatherer societies[8] has been conducted within changing theoretical frameworks influenced progressively by numerous overarching theoretical structures variously focussed on economy, culture, behaviour, environment, ecology, function and socio-cultural changes (Trigger 2006:520). Darwinism, Marxism, neo-Marxism, materialism, idealism, neo-Darwinism and macro-evolutionary theory have been the leading influences in this field (Bettinger 1991:1–3, 10, 12, 131–149,151–212; Smith 2015; Trigger 2006:520–521; Zeder 2012). Diverse theoretical modelling, based on both ethnographic and archaeological research, has provided a basis for interpreting socio-economic and cultural changes over time. However, ethical considerations in regard to the people involved in these studies has often been a minor consideration, certainly during the 18th, 19th and early 20th centuries. For instance, the

[8] Subsistence systems encompassed by the term 'hunter-gatherer' may also encompass elements of resource management such as the use of fire to improve natural pasture and the replanting of components of USO bearing plants. Such activity is described as 'domiculture' (Hynes and Chase 1982:38).

discredited racist concepts of linear cultural evolution which have been prominent and damaging to Indigenous peoples (Asch 1997:269; Deloria 1995:64–65; Smith 1999:38).

Ethnographically, hunter-gatherer societies are extremely diverse (Kelly 1995:2) which has encouraged concomitant and expansive anthropological and archaeological research into explanatory theories of subsistence and socio-economic organisation. However, in the practice of anthropological research, Bettinger (1991:1) argues that in general:

> …students of hunter-gatherers have historically adopted interpretative perspectives that are comparative, evolutionary and materialist…

As a sub-discipline of modern (post 1880) archaeology, hunter-gatherer societal studies have been embedded within a succession of conceptual and competing frameworks, and wider debates, on the way archaeology is conducted as a discipline (Trigger 2006:535). Trigger (2006:535) lists these as culture history, functional processual and post-processual archaeologies which reflect a transition over time, sequentially encompassing an emphasis on descriptive methodology, the application of scientific methods in the analysis of behaviour and change and culminating in a focus on the impact of ideas and relationships on culture and change (Trigger 2006:485–486).

This analysis explores relevant theoretical concepts in association with a consideration of the major themes of 'intensification' and the introduction of BSD within Aboriginal societies in Australia. These concepts include those based on socio-economic and cultural factors including neo-Marxism and optimal foraging models, and the evolutionary composite concepts that encompass neo-Darwinism and macro-evolutionary theory. Together, these are considered to have the most significance for the Australian archaeological context, paralleling the historical perspectives of local debates commonly used to examine the key theoretical drivers of change within Australian Aboriginal societies during the Holocene, and recent theoretical debates regarding research into hunter-gatherer societies more generally. In exploring both socio-economic and evolutionary conceptual frameworks for the purposes of this review it is noted that both socio-economic (Beaton 1983, 1985; Bowdler 1981; Lourandos 1980, 1983, 1985, 1997, 2008; Lourandos and David 1998; Lourandos and Ross 1994:54; Ross 1985; Ross et al. 1992; Williams 1988) and human evolutionary ecology perspectives (Frankel 1991; Pardoe 1994, 1995; Smith 1989) have a long history in

Australian archaeological research. In this context a dichotomy between internalist and ecological perspectives is limiting and undesirable (Veth et al. 2000:61–62). The resolution of this dichotomy requires an acknowledgement of the interactive process involving ideas, environment and organisation which have been central to human development since the origin of *Homo* spp. some three million years ago.

4.3.2 Neo-Marxism

Neo-Marxism, or structural Marxism, had its origins in France during the 1960s as a response to the failure of classical Marxism to provide a viable model for what was historically perceived as 'primitive' classless societies (Bettinger 1991:136–138; Trigger 2006:444–445). This approach rejected neo-evolutionism, traditional structuralism, cultural materialism and cultural ecology, each of which treated cultural change as external to social relations and assumed humans to be passive actors with external environmental factors predominant (Trigger 2006:445). Neo-Marxists viewed social conflict derived from competing and contradictory interests as the major source of change within classless pre-agricultural societies (Bettinger 1991:137–138; Trigger 2006:445–446). In such societies this manifested as conflict over the control of food and labour, intergenerational power, individual and family status, gender roles, high value resources, traditional knowledge and ritual responsibilities and benefits (Bettinger 1991:138; Trigger 2006:445–446). Bettinger (1991:446–447) critiqued this model centring his argument on a basic misunderstanding of hunter-gatherer behaviour and social organisation. Notwithstanding this, the intensification debate in Australian archaeology, centred on the mid Holocene and later, draws significantly from a neo-Marxist model (Lourandos 1983, 1997).

In the context of societies based on gathering, hunting and fishing, Bender (1978:205, 1981) defined intensification as an increase in the quantity of resources taken from a given unit of land. However, this can reflect higher or lower productivity depending on the technology deployed and time invested. Bender (1978:205) makes this point to emphasise that intensification must be 'explained in terms of pressure'. This is an important observation, whereby intensification may not be specifically about increasing quantities of food per se or associated with social or demographic change (Bender 1978:206). For instance, intensification in resource exploitation which occurs in response to a greater demand for food resources per head of population requires explanation. Bender (1978:107) critiqued the processual approach as 'ecosystemic' with a focus on external agency, e. g., an environmental bias expressed as demographic saturation associated with restricted territories, imposed sedentism and a move to food production (horticulture, pastoralism and/or agriculture). Bender (1978:208–209) rejected this premise on the basis of a lack of evidence, preferring demography as an expression of cultural organisation and the relations of production rather than the 'prime-mover' or principal driver. Bender (1978:210–214) cited numerous ethnographic examples of hierarchical and alliance structures; social competition and organisation; and control of production in support of her argument for the primacy of socio-cultural factors in classless pre-agricultural societies. This is augmented with archaeological evidence from western Asia, Europe and the Americas indicating extensive exchange networks, elite burials, craft specialisation, food storage and ceremonial networks prior to the establishment of state level societies (Bender 1978:214–218). The emphasis lies not so much with a commitment to food production but with the development of social systems in a mosaic of separately evolving individual societies, such that 'it is the social relations that articulate society and set the evolutionary pattern' (Bender 1978:218, 1981:154; see also Gamble 1981: 215; Kus 1984; Wolpe 1980).

4.3.3 The Australian socio-economic intensification model

The purported continental intensification model for Aboriginal Australia in the Holocene is associated with '...questions of change and dynamics within hunter-gatherer societies of the past, especially regarding demographic, socioeconomic intensification and sociocultural factors' (Beaton 1983, 1985; see also Bowdler 1981; Lourandos 1983; Lourandos and Ross 1994:54–55; Ross 1985; Ross et al. 1992; Williams 1988). The hypothesis presents an argument against traditional passive views of hunter-gatherer societies reacting to the vagaries of the environment in a deterministic way. The socially derived perspective was based on an interpretation of the archaeological evidence which indicated the potential roles of intra-societal factors such as demographic growth, and related socio-economic changes (including diet choice) in Australian Aboriginal societies, particularly during the mid Holocene (Beaton 1983; Lourandos 1980; Lourandos and Ross 1994:57–58). Ross et al. (1992:107–109) conceptualised a three phase transitional model for the occupation of the Australian arid zone which proposed that environmental conditions were initially the most significant influence on Aboriginal groups prior to and during the LGM. However, Ross et al. (1992:107) posited that from the early Holocene the archaeological record was not in phase with variations in climate and consequently social factors were an increasingly dominant influence on landscape use and adaptation through the Holocene (see also Lourandos [1997] and Veth [1995, 1999, 2006]).

The archaeological evidence for a post 4000 cal BP social and economic intensification in Australia, often cited in support of a socially driven hypothesis, includes grass seed grinding, the exploitation of edible nuts (e. g. *bunya* nuts—*Araucaria bidwilli*), harvesting of the Bogong moth (*Agrotis infusa*), the use of terrestrial and aquatic underground storage organs (USO), inter and intra-regional trade, fish traps, fresh water eel management, diffusion of art styles and increases in population, sedentism and social complexity (Frankel 1995:652–653; Lourandos 1983, 1997; see also Beaton 1985; Smith et al. 1993; Tibbett 2004). Evidence cited also includes the intensive exploitation of marginal and low trophic toxic foods such as Cycad nuts, including *Bowenia, Cycas, Lepidozamia* and *Macrozamia* spp., which require extensive processing to be edible (Asmussen 2005, 2008, 2009, 2010a, 2010b; Beaton 1977, 1982; Lourandos 1997; Tuechler et al. 2014). However, Asmussen (2008:99) disputed social interpretations of economic intensification in this context, concluding that the archaeological evidence does not support large scale production consistent with large ceremonial gatherings as proposed by Beaton (1977, 1991a, 1991b) and Lourandos (1997:143). Also, further research indicates earlier use of labour intensive plant food processing techniques including seed grinding (65–53,000 ya at Madjedbebe) and eel management and harvesting (~7,000 ya in western Victoria) (Florin et al. 2020:4–5; McNiven 1998:83).

In their extensive examination of the archaeological record in far western New South Wales, Holdaway et al. (2008) concluded that the apparent increase in quantity and range of archaeological material was a function of taphonomic processes and not indicative of an intensification in that region during the mid Holocene. Whilst erosion and deposition had complicated the interpretation of the material evidence, a detailed dating program and technological analysis of artefacts indicated that for the far western areas of New South Wales that were sampled, there was no evidence of higher populations, sedentary occupation or an increase of socio-economic complexity (Holdaway et al. 2008:410). As a consequence, Holdaway et al. (2008:411) suggested that socio-economic interpretations for mid Holocene intensification required further testing and potentially a modification of theoretical frameworks. Similarly, Bettinger et al. (2015:173) criticised theoretical perspectives of intensification in the American context that he concluded were based on insufficient data. Hiscock (2008:219–244) critiqued late Holocene population growth models for Aboriginal societies which provided the basis of the arguments for a socio-economic intensification, citing a lack of evidence because of preservation issues and issues with interpretation, concluding that:

> Claims for far larger population sizes at the end of the pre-historic period have not been demonstrated and other, equally plausible, images of past population change can be offered.

Later work by Williams et al. (2015a:106) used a summed probability analysis (SPD) of ^{14}C dates in conjunction with climate data argued for environmentally influenced change in past Australian Aboriginal societies on a continental level. The research suggested that during the Holocene:

> …there is evidence of increasing populations with the establishment of home-range strategies, initiation of new corporate identity, and development of more complex technological procurement strategies.

Williams et al. (2015b:1) argued that the MHCO (9000–6000 cal BP), was associated with a:

> ...rapid expansion, growth and establishment of regional populations across about 75% of Australia, including much of the arid zone.

This period also saw the proliferation of Pama-Nyungan languages, backed artefacts, a move to more sedentary lifestyles and a broadening of diets, signalling social, cultural and economic innovations (David 2002; Lourandos 1997; Smith 2013; Williams 2015b:2). The period 4500–2000 cal BP experienced an extended El Niño-Southern Oscillation (ENSO) and increased aridity, population fragmentation and decreased territoriality (Williams et al. 2015b:12). The period post 2000 cal BP experienced a climatic amelioration with the onset of La Nina climate conditions and an ‘intensification of mobility strategies and technological innovations that were developed in the early to mid Holocene’, leading to increased populations, increased territoriality and the development of complex religious and social systems in order to control resources (Williams et al. 2015b:1, 12). Clearly, the assignment of social relations as the dominant factor in socio-economic and cultural change is uncertain and ignores evidence of an association of climate variability with socio-economic responses by Australian Aboriginal peoples (Hiscock 2008:249–252). In their review of ecological approaches in Australian archaeology, Veth et al. (2000:61–62) concluded that 'despite the problems inherent in the use of palaeoecological data and modelling, the archaeological record cannot be profitably divorced from its environmental context.' Similarly, Giddens (1981:166–167) in his critique of historical Marxism states:

> ...there are both endogenous and exogenous sources of change in human societies but that neither has generalised primacy over the other. In some circumstances, influences emanating from 'outside' a society can entirely wreck or even eradicate that society; in other instances, there are strongly marked endogenous sources of societal transformation.

The reality is somewhere in the middle ground between 'internalist and ecological explanation' and an understanding of the complex interaction of social and ecological forces that can only be improved by continuing multidisciplinary research (Veth et al. 2000).

4.3.4 Middle range and optimal foraging theory

From an archaeological perspective, the anthropological study of hunter-gatherers has contributed several interpretative theories, including structural-functionalism, environmental possibilism, structuralism, cultural ecology and neo-functionalism, which are basically represented by two models (Bettinger 1991:2). The earliest developmental models emphasised social progress, directional evolution and social Darwinism, characterised by romanticism, implicit racism and inherent concepts of European superiority (Bettinger 1991:3–5; Kelly 1995:6–10; Trigger 1980, 2006:167–171, 173, 189–191, 409). As Smith (1999) argued such theories have been extremely damaging for Indigenous peoples. These models were largely, but not entirely, superseded in the latter half of the 20th century by an ecological model emphasising adaptation, socio-economic equilibrium and adaptive responses to challenges which often incorporated complex solutions, including social, technical and religious components, often in combination (Bettinger 1991:5). Within this new paradigm there was an emphasis on archaeological data and related interpretations which sought explanations in terms of 'functioning adaptive systems' (Bettinger 1991:61). This led to the formulation of 'testable' models such as 'middle range theory' (MRT) and 'optimal foraging theory' (OFT) (Bettinger 1991:62). The latter being an import from the discipline of biology (Bettinger 1991:83). MRT and OFT are related theoretical concepts with a similar materialist foundation (Bettinger 1991:77–82). The former is focused on the interpretation of the archaeological record with an emphasis on site formation processes, and the latter on behavioural explanations based on individual rationality, and reliance on micro-economic theory, from which OFT received its intensive use of mathematical analysis. After 1980 OFT became a popular framework for the evaluation of diet breadth models, resource diversification and intensification typically seen to precede the transition to food production. Zeder (2012:245–256) provided a well-reasoned critique of this approach based on numerous archaeological studies which contradict OFT predictions of resource diversification. This critique is essentially argued on the basis of its simplistic and mechanistic approach to individual behaviour and economic optimality. The theory ultimately falters on the exclusion of environmental factors which impact resource availability in most OFT explanatory models. Zeder (2012:255) argued that most examples of the broadening of diet are associated with improving climatic conditions and increasing resource availability whilst OFT models, in contrast, posit a reduction in resource efficiency as a driver of diet diversification (Zeder 2012:242–244). In consequence, Zeder (2012:254) preferred a niche construction approach which is discussed below.

Bettinger (1991:81–82) critiqued MRT because of 'predictive indeterminacy' indicated by numerous examples of contradicting interpretations of the same archaeological data set, and hence conflicting conclusions about hunter-gatherer behaviours. He further critiqued OFT, for assumptions of economic rationality in prey choice, which he believes are basically flawed at the individual level (Bettinger 1991:107–111; see also Zeder 2012:256). Whilst Bettinger (1991:110–111) accepts that there are benefits in middle-range research, he highlights a neglect in the development and application of high level theory in studies of 'pre-agricultural' socio-economic systems, and the need for a coherent general theoretical framework for future research. Smith (2015:228) emphasised this deficiency in OFT and its subordinate models, outlining that:

> They were not derived from or informed by any higher levels of evolutionary theory (i.e., evolutionary ecology and neo-Darwinian evolutionary theory); rather they came into biology through a side door; and are far from being embraced as an established principle and standard approach in biology.

Smith (2015:228–229) argued that despite acceptance by many researchers in anthropology and archaeology, recent work in multiple disciplines has found optimisation theory (OT) is unsupported by real-world datasets. Consequently, OFT has attracted criticism as an unsatisfactory explanatory frame work for research into the transition of human economic strategies from the terminal Pleistocene (see also Smith [2012] and Zeder [2012]). This has led to the development and adoption of Niche Construction Theory (NCT) as an alternative explanatory framework for this research. Not-with-standing this dichotomy, Jones and Hurley (2017) have identified that some researchers see compatibility between these approaches (see Broughton et al. 2010; Piperno et al. 2017; Stiner and Kuhn 2016).

4.3.5 Niche construction theory (NCT)

A more recent widening of this debate has been the promotion of neo-Darwinian or evolutionary perspectives based on selection, function and adaptation which aim to transcend materialistic, functionalistic or idealistic concepts . The intention was to reduce value laden interpretations through the application of an evolutionary framework to the analysis of the archaeological record (Trigger 2006:486). This extends to a wider view of evolution than simple biological processes that act at the level of the individual, positing an evolutionary matrix and process of adaptation which includes the interaction of ideas, material culture and innovation that can create change in a much smaller timeframe (Trigger 2006:486). This originated as a new theoretical framework in biology, which was termed the 'extended evolutionary synthesis' (EES) or macro-evolutionary theory (MET) (Laland 2014:161; Smith 2015:229), emerging in response to limitations in standard evolutionary theory (SET) which struggled to explain what was actually observed in the study of evolutionary processes in response to change (see also Pigliucci and Muller 2010; Richards and Pigliucci 2020).

The difference between these evolutionary approaches, from both a biological and archaeological perspective, is the issue of directionality and intent (Smith 2015:229). Neo-Darwinism rejects the possibility of directional progressive evolution at the individual level; however, the converse is argued for macro level processes (Smith 2015:229). The key argument reflects the role of cultural evolution in the response of a community of individuals to change, in a time frame much quicker than biological processes could allow (Laland et al. 2013; Laland and O'Brien 2010; Smith 2015; Zeder 2009a, b, 2012). In this sense organisms, potentially both deliberately and unwittingly, actively engineer their environment (construct a niche) to optimise their outcomes, thus impacting on future outcomes. MET, and consequently NCT, is situated within the top tier of evolutionary theory 'as an equal and antithetical alternative to neo-Darwinism' (Smith 2015:230). In this context, cultural niche construction, as a component of human behavioural ecology, is securely linked to higher level evolutionary theory and can be argued to be a more plausible alternative to simplistic optimality theory and its associated models (Smith 2015:230–231).

NCT developed from macro-evolutionary theory approximately 25 years after Flannery's (1969) conceptual contribution of the BSR framework (Smith 2015:229). Flannery (1969) identified a broadening in hunter-gatherer diets in south-west Asia prior to the domestication of animals and plants which preceded the development of agriculture in that region (Zeder 2012:242–243). The archaeological record indicated the introduction of previously ignored lower ranked resources into local diets within a context of population growth and overflow from optimal into more marginal resource environments (Zeder 2012:242). The resource depletion model predominated in OFT themed research which centred on imbalances between carrying capacity and population levels and consequently increasing diet diversity (Zeder 2012:242). Over time exceptions to this model became increasingly obvious, leading to the emergence of alternative perspectives that recognised the active and deliberate modification of environments (i.e., the construction of a niche) to improve economic returns and the implications associated with these processes (Zeder 2012:242, 247–252, 257).

4.3.5.1 Critiques of niche construction theory

Critiques of NCT associated with proponents of the modern synthesis of evolutionary theory question whether NCT is an evolutionary process or is simply an agent acting on evolutionary processes (Constant et al. 2018; Dawkins 2004). NCT proponents argue for its acceptance as a crucial component of an extended synthesis of evolutionary theory. Gupta et al. (2017:499) perceive a repetition of a limited set of arguments and inappropriate analogies in the literature associated with NCT and are critical of attempts to create an 'academic niche'. Gupta et al. (2017:499) view this as an example of a general problem in scientific practice where individuals accentuate and bolster claims of novelty in their work (see also Robinson and Goodman 2011; Teixeira et al. 2013 and Maes 2015). In this context it is argued that SET adequately incorporates NCT as a common ecological phenomenon which does not require its acknowledgement as a 'fundamental evolutionary process in its own right' (Gupta et al. 2017). Gupta et al. (2017) see NCT as an unnecessary and superfluous mechanism which is unsupported by the evidence provided by its proponents. The modern evolutionary synthesis (MS) treats adaptation arising from niche activity by organisms in the same way as adaptations arising from random environmental changes (Constant et al. 2018). Standard evolutionary processes act through the natural selection of traits that enhance fitness (or have a neutral effect) and eliminate traits that do not (Constant et al. 2018; Scott-Phillips et al. 2014; Laland 2004). In contrast, constructed environments can be inconclusive in achieving reproductive success and optimisation of inclusive fitness, hence NCT is critiqued for a perceived lack of reliable predictions about adaptation (Constant 2018; Scott-Phillips et al. 2014). However, advocates of NCT maintain that the study of niche construction and other developmental processes in evolution are critical to understanding and facilitating the progression of an extended evolutionary synthesis (Scott-Phillips et al. 2014:1239).

NCT is a concept which continues to undergo a considerable and healthy debate about its status within the evolutionary theoretical framework (Scott-Phillips 2014). Sceptics align with causation in evolution as a unidirectional process with natural selection resulting in genotypic changes and stable adapted phenotypes, while adherents focus on the co-evolution of organisms and their environment through intended or unwitting modification (Constant et al. 2018; Odling-Smee et al. 2003; Scott-Phillips 2014).

4.3.6 Broad spectrum revolution

As indicated previously, the BSR was a hypothesis which outlined a significant but diverse phenomenon first associated with western Asia that was labelled 'the broad-spectrum revolution' (BSR) (Edwards and O'Connell 1995; Flannery 1969; Zeder 2012). At this time, diets are thought to have shifted to include previously marginal and low trophic foods not previously targeted. This phenomenon has been variously attributed to intra group social change and the development of 'complex' social organisation, the introduction of new technologies, sedentary behaviours, demographic change, new food storage strategies and climatic change associated with the terminal Pleistocene (Edwards and O'Connell 1995). The BSR became synonymous with dietary diversity, resource intensification and stress associated with population growth and resource availability; and ultimately provided a conceptual framework for the domestication of plants and animals and the emergence of agriculture (Zeder 2012:242). Zeder (2012:257) indicated that NCT was formulated as a new paradigm in biology, and subsequently in pre-agricultural socio-economic studies, which linked:

> …organisms and their environment as a major driver of evolution. Niche construction theory is grounded in a 'macro-evolutionary' approach that recognises complex hierarchical processes and views organisms as co-determined rather than as separate entities with independent properties (Gray 1987:90).

The archaeological record in many different regions of the world suggests that at a local level, the BSR was likely underpinned by a resource rich, diverse and predictable environment over the annual subsistence cycle which encouraged sedentary behaviour and favours an NCT perspective (Zeder 2012:258). This is demonstrated in the Southern Levant, Central Anatolia, Fertile Crescent, North America and north-eastern Asia with the onset of warmer and wetter climatic conditions during the late Pleistocene-early Holocene transition (Zeder 2012:258).

4.3.7 The relevance of theory

As outlined previously, theoretical models developed from the observation and interpretation of cultural and socio-economic practices serve as frameworks which can be tested by new data from more recent research. The models outlined above are considered to be the most relevant in relation to this study of Aboriginal earth mounds on the Calperum floodplain and will be considered further in the analysis which follows.

4.4 The Australian 'transition'

In Sahul, the continental entity comprising Australia and New Guinea following the LGM, provides a contrast in subsistence strategies between the highlands of New Guinea and the rest of the continent at that time. A horticultural transformation occurred in the northern highlands (of New Guinea), which Hope and Golson (1995:818–830) and Golson (1991) date from approximately 10,000–9000 cal BP and which entailed the domestication of several plant and animal species (see also Denham et al. 2004:274–278; Denham and Haberle 2008:493: Denham et al. 2017:187–200). The timing of this transformation remains contentious, as pollen evidence does not indicate primary forest clearance until approximately 2000 years later, suggesting agricultural activity was localised or potentially occurred later (Haberle and David 2004:175; see also Haberle et al. 1991; Spriggs 1996). In the remainder of the continent, gathering, hunting and fishing based socio-economic systems continued on multiple trajectories influenced by a diversity of environmental contexts and the socio-cultural mosaic of individual dynamic societies which were in place by the time of the European invasion. This also included other subsistence systems such as eel optimisation and harvesting and, the use of fish traps and the detoxification of inedible nuts as discussed previously (Williams et al. 2015b:6–12)

The application of theory and models derived from anthropological and archaeological research into socio-economic transitions in European, Asian and North American hunter-gatherer contexts have provided useful frameworks to inform the archaeological study of past Australian Aboriginal societies. Edwards and O’Connell (1995:769, 744) examined the subject of BSD in Australia with reference to the arid zone, which constitutes approximately seventy percent of the Australian continent where evaporation equals or exceeds precipitation. The occupational history and land use of this region has been studied intensively through ethnographic and archaeological evidence of processing technologies such as seed grinding and other marginal resources with a focus on socio-economic factors and responses to environmental change (Edwards and O’Connell 1995:774). However, more recent evidence of the deep antiquity of seed processing in Australia weakens the argument that seed exploitation represented an example of diet broadening from the mid Holocene (Florin et al. 2020:5).

In consequence of its wide distribution, Edwards and O’Connell (1995:780) attributed the global expression of the BSR to ‘very general processes’, active in diverse locations within a relatively similar time frame. In the Australian continental portion of Sahul, the ‘revolution’ was posited to have occurred from the mid Holocene, significantly later than that demonstrated in other geographical contexts (Edwards and O’Connell 1995:780–782). Thus, challenging the climatic influence of the terminal LGM as a key initiating factor, at least on this continent (Frankel 1995:649–655). Frankel (1995:649–655) details the history of archaeological practice, attitudes and the development of archaeological understanding in Australia since European colonisation. Frankel (1995:652) critiques early hypotheses of socio-economic conservatism (a concept which is largely absent in archaeological theory due to its emphasis on socio-economic and/or cultural change) as a characteristic of pre 4000 cal BP Australian Aboriginal populations (see also Mulvaney 1971; Bowdler 1993; Holdaway 1995:794–795). This cultural and socio-economic conservatism had been inferred for early Aboriginal societies as an explanation for the seemingly late (in a global sense) socio-economic transformation which was posited to have occurred from about 4000 cal BP (Frankel 1995:653–654).

4.5 Social, demographic and resource related perspectives

Edwards and O'Connell (1995:775–777) adopted an OFT perspective in their critique of three categories of explanation for the introduction and use of BSD in Australia (see also Zeder 2012:245). The three categories included social influences, the relative abundance of lower trophic broad spectrum foods and depletion of higher rated resources. In consideration of the explanatory premise of social factors, Ross et al. (1992) argued that the arid zone, in concert with the rest of the continent, experienced significant population growth during the mid Holocene and intensified use of marginal resources as a feature of increased production. This was posited to be a consequence of social factors and characterised by technological and organisational innovation, wider exchange networks, population growth and larger ritual gatherings. Veth (1987, 1989, 1993; Veth et al. 1990) also emphasised intensification involving key innovations in social organisation and multiple technologies suggested by an 'efflorescence' of sites in the late Holocene containing 'small tool' components (indicating hafting) and grindstones (Veth et al. 1990:63–64). Whilst Edwards and O'Connell (1995:779) concede that social factors can and do act in many varied ways they discounted social processes as a prime driver of BSD because of a lack of specific archaeologically testable criteria.

Edwards and O'Connell (1995:775) also questioned the validity of the argument for the adoption of a particularly abundant (low trophic) food resource if the costs of procurement are too high in comparison to higher trophic foods. They favoured depletion of higher ranked foods as the more persuasive driver for adoption of lower ranked resources. Smith's (1988, 1989, 1993) model of demographic stress through climatic change and consequent lower availability of preferred foods is consistent with this hypothesis but suffered criticism at the time, because of a lack of evidence for population growth from the mid Holocene (Edwards and O'Connell 1995:776). However, the later SPD analysis by Williams et al. (2015 a, b) has provided support for an interactive model including population growth, climate change and a fluctuating resource base (see below).

4.6 Innovation, lower ranked resources and temporality

Edwards and O'Connell (1995) suggested the sudden adoption of seed processing in the mid Holocene to be unlikely since they view this resource as being critical to occupation of the arid zone from first access. The lack of evidence of seed grinding equipment, at the time, in LGM and prior deposits, they considered to be a factor of low population density and small sample-size (Edwards and O'Connell 1995:776). This point is reinforced by recent research which puts initial occupation of the arid zone by Aboriginal people prior to 50,000 cal BP suggesting a long association with the region over time and the likely exploitation of grass seeds as a seasonally abundant resource (Hamm et al. 2016). The discovery and analysis of seed grinding equipment at Cuddie Springs in New South Wales, dating to 30,000 cal BP, also supports this conclusion (Fullagar and Field 1997). The evidence suggests the adoption of seed processing and an early focus on BSD significantly prior to the LGM, possibly in response to the advent of adverse climate conditions at about 30,000 cal BP but potentially earlier (Hayes et al. 2022; Florin et al. 2020; Fullagar and Field 1997:304–306; see also Fullagar et al. [2015:9–15] and Hiscock [2008:122]).

Research conducted at Riwi Cave in the Kimberley Region, Western Australia, indicates that the use of earth ovens in Australia has a potential history extending from at least 34,000 cal BP (Whitau et al. 2018). The use of earth ovens and heat retainer cookery has significant antiquity in northern hemisphere contexts dating from approximately 30,000 and 10,000 years ago respectively (Black and Thoms 2014:204–205). These are found extensively in Europe (Anthony et al. 2001; Beamish and Ripper 2000; Buckley 1991; Gillespie 1991) and North America (Black et al 1997; Hawley 2003; Saunders and Allen 1994; Saunders et al. 1997; Smith and McNees 1999; Sullivan et al. 2001). The use of this technology has provided access to nutritional resources contained in terrestrial and aquatic plant roots otherwise inaccessible through the inability of human digestive tracts to process complex carbohydrates such as inulin (see Martin [2006] for a detailed overview of this subject, see also Morrison et al. 2022 for an examination of the Aboriginal use of ground cookery). The evidence from Riwi outlined above indicates that this form of cooking was known to some Aboriginal groups from at least 34,000 cal BP (Whitau et al. 2018).

The apparent appearance of Aboriginal earth mounds in the Australian archaeological record after 5000 cal BP (Figure 3.9) potentially suggests technical and/or logistical innovation, and an innovative reorganisation of intra group socio-economic resources and strategies. The application of innovation in these processes allowed the intensive exploitation of previously under-utilised resources through the large scale use of heat retainer technology at least from the mid Holocene, as noted earlier in this thesis. However, taphonomic factors may have truncated the record since these features are typically found in active wetland environments subject to erosional and depositional processes (Jones et al. 2017; Jones et al. 2022; Westell and Wood 2014). The oldest known earth mounds in Australia are those reported by Martin (2006) located on the lunettes of palaeo-lakes near Balranald on the western end of the Hay Plain in south-western New South Wales in the MDB. The earliest date obtained was 4888 cal BP (WK-4101) from a sample of charcoal from layer 4b on the Tchelery1 mound. Earth mounds in the MDB are more typically found in active riverine environments closer to main river channels and anabranch systems with available dates in such locations (in the nearby central Murray region) starting from about 3100 cal BP (Figure 3.9) (Jones 2017; Jones et al. 2022; Westell and Wood 2014). Consequently, because of the active erosional and depositional environments in which earth mounds are found, it is quite possible that earth mounds could have been established earlier than indicated by the age estimates obtained to date.

4.7 Earth mounds and economic intensification

Lourandos (1983:86–87, 1997:216–218) hypothesised that earth mounds reflected strategies enabling the use of marginal wetlands for the exploitation of a broader set of resources and a higher level of production than previously targeted. As indicated above, the timing of this process contrasted with the transformations which occurred earlier elsewhere in the world (Frankel 1995:652). Change, as identified in Australian Aboriginal societies prior to the apparent intensification of the late Holocene, had been:

> …seen largely as responses to fluctuating climate and resource availability: people do the same things in slightly different places (Frankel 1995:652).

Lourandos (1983, 1997) argued that procurement strategies diversified in response to an increase in population growth and increased sedentism in the western districts of Victoria. Lourandos (1983, 1997) cited this as evidence of a regional example of a continent-wide social and economic transition from the mid Holocene. Social factors, such as increased intergroup ceremonial and alliance network activity were favoured as the key driver of changes in socio-economic practices which increased the availability of resources to satisfy existing and changing social requirements in an increasingly challenging environment (Lourandos 1980:256; McNiven et al. 2006:9). Williams (1988:67, 220–221) added to this perspective through her interpretation of western Victorian earth mound clusters as the remains of 'villages' representing intensified levels of production and evidence of greater social complexity. In addition, Williams (1988:220–221) further interpreted the development of social complexity to be primarily due to social agency rather than external influences such as climate change.

In contrast, Hiscock (2008:253) argued against the possibility of earth mounds as the remains of 'villages' which indicate a highly sedentary population in the region, as proposed by some researchers (Flood 2001; Williams 1985, 1988). Opponents of social hypotheses for the origins of earth mounds in the MDB have argued that contemporaneity between mounds has not been established and consequently, more evidence of complexity and social change is required (Frankel 1991:85; Head 1990:85; Hiscock 2008:253; Holdaway et al. 2008). Frankel (1991:85) favours a simpler explanation involving the repeated accumulation of earth oven material in the same location over time. In this interpretation, some of these features subsequently served as occupation sites, in a region which was characterised by poor drainage and a climate which became progressively wetter and more variable from 2500 cal BP (Frankel 1991:85).

Bird and Frankel (1991:189–190) and Hiscock (2008:188–189) make the distinction between cumulative directional change (i.e., intensification) and short-term adjustments in response to changing circumstances, concluding that the archaeological evidence from western Victoria and south-eastern South Australia reflects hunter-gatherer societies responding to external and internal influences, but not in a directional way.

4.8 Transitional change–when?

Frankel (1995:652–653) emphasised that archaeological theories and models have largely focussed on the identification and explanation of socio-economic and cultural changes in the Holocene and speculated on the possible factors operating at the local level which might have prohibited this from happening earlier in the Australian context. Frankel (1995:653–654) ultimately concluded that artificial conceptual boundaries (e. g., the Pleistocene/Holocene boundary) have distorted interpretation of what he terms 'a unilinear evolutionary trajectory' and a potentially mistaken view of an emergent 'false image' late Holocene social and economic intensification, distorting the understanding of longer-term processes. Hiscock (2008:106–128) provided an additional perspective to this debate, indicating that:

> Pleistocene human societies in Australia were not uniform or unchanging; nor did they all progress directionally from simple technological and cultural beginnings.

From his review of the archaeological record, Hiscock (2008:120) outlined an image of sophistication, diversity and change for Pleistocene populations in Australia citing numerous case studies in support of this argument. These include the presence and use of ground stone axes prior to 25,000 cal BP, early use of grinding stones, heat treatment of stone in the production of tools, fish nets, the use of bone, wood and other organic tools as well as evidence of large gatherings indicative of social networks (Hiscock 2008:121–123, see also Geneste et al. 2010). Such societies were demonstrably diverse at the local level but left a record which was difficult to interpret because of taphonomic processes (Holdaway et al. 2008:403; Ulm 2013:182–192). However, Hiscock (2003:42–45, 264–267) concluded there was an underlying dynamism engendered with economic and cultural diversity, emphasising the environmental and human agencies that influence the evolutionary processes which have driven continuous social, economic and ideological reorganisation since the first entry of people into Sahul. This reflects the emergence of economic and cultural strategies as adaptations to a variety of circumstances and challenges; and supports a dynamic view of the socio-economic and cultural trajectories of late Australian Pleistocene societies into the Holocene rather than a sudden socio-economic and cultural emergence. Similarly, the theories supporting the adoption of BSD as a distinct transition in the mid Holocene are problematic given the abundant evidence of diverse broad-based procurement strategies used by Australian Aboriginal peoples from at least 30,000 cal BP. However, technical innovation and changes in the logistical scale of some procurement strategies (e. g., more intensive use of earth ovens to access additional resources in wetland environments) may have some relevance in the context of climatic variation, demography and the adaptational responses of groups of people in specific local contexts from about 5000 cal BP.

The association of adverse environmental conditions with the implementation of technical and/or logistical innovations; and the exploitation of lower trophic resources from the mid Holocene is suggested by the time series analysis provided by Williams et al. (2015 a, b). The analysis indicates a hiatus in population growth in Australia associated with increasing aridity from 5000 to 4000 cal BP following the end of the mid MHCO and suggested the adoption of innovative techniques for improving access to lower trophic nutritional resources at that time (Williams et al. 2015 a, b). Repeated demonstrations over time, of the relationship between repeated adverse episodes of climate change, resource restriction, the use of innovative processing and cooking techniques, and increased exploitation of lower trophic foods in Aboriginal lifeways indicates an inherent flexibility in Australian Aboriginal subsistence strategies. Such flexibility demonstrates the ability of Aboriginal cultural and socio-economic systems to adapt quickly to external challenges. This was not specifically confined only to the mid Holocene, since the rate of population growth, landscape use and the exploitation of broad spectrum resources appears to have accelerated from about 5000 cal BP albeit potentially moderated by periodic variations in climate (Williams et al. 2008a, 2015a, b).

4.9 Chapter summary

A short list of relevant theoretical frameworks and models have been briefly outlined and reviewed above from an Australian archaeological perspective. They have been reviewed for their potential to explain change in Australian Aboriginal societies during and following the Pleistocene-Holocene transition. Research in other global contexts have failed to establish a successful framework that provides for chronological differences and the complexities of variation noted in the Australian archaeological record at both regional and local levels.

Neo-Marxist derived continental frameworks arguing for socially driven change and enduring inequality are tentative at best and are readily critiqued because of socio-economic variation amongst Aboriginal groups at sub-regional levels and deficiencies in supporting archaeological evidence, since ideology and social practices are very difficult to tease out of the material record (Hiscock 2008:264–265). Even in an ethnographic study of seven Aboriginal groups Keen (2006:19) produced a somewhat ambivalent conclusion in this context, suggesting considerable social and cultural diversity was a major constraint and emphasised the need for further research. As a consequence, social models without an ecological framework fare poorly as general explanations for human behaviour.

An examination of behavioural change at clan and group levels can potentially demonstrate a spectrum of socio-economic strategies and considerable diversity in the application of innovation. A comparative analysis of the production niches of hunting, gathering and fishing populations in hydraulically similar but different climatic contexts which potentially exhibit similar adaptive strategies has not been done at this time in Australia. The brief comparison of earth mound research conducted in south-eastern and northern Australia (Chapter two), demonstrates similarities in resource base richness, significant seasonal environmental variability, and similar adaptive strategies in response to these factors. As previously outlined, these adaptations appear to have arisen independently at about the same time in regions which are separated by several thousand kilometres, are located in different climate zones and demonstrate a differently structured resource base.

Chapter Five: The Archaeological Significance of Riverine Systems in Australia

5.1 Introduction

This research investigates Aboriginal earth mound features located on the Calperum floodplain near Renmark in the South Australian Riverland, which is part of the wider MDB (Figure 5.1). The Calperum floodplain is located on the Murray River and is part of an extensive anabranch fed system of an ephemeral system of lakes, billabongs and lagoons. This floodplain and other riverine environments in the MDB and northern Australia where earth mounds are typically found, were highly productive and supported Aboriginal societies at higher population numbers than regions of lower water availability (due to seasonal inundation and an associated surge in numbers of animals, fish, shellfish, crustations and plant growth which followed).

5.2 South-eastern Australia

The MDB dominates the south-eastern portion of the Australian continent that extends west of the Great Dividing Range (see Figure 5.1). The Basin comprises a drainage catchment for rivers and streams emerging from the Great Dividing Range and empties into the Southern Ocean in South Australia. The high productivity of the riverine systems within the region, in both modern and pre-contact times, has been instrumental in supporting Aboriginal peoples in this area of the continent from at least 50,000 cal BP (Hamm et al. 2016). It is bound to the north-west by the Carnarvon Range, compromising 1,059,000 square kilometres or 14% of the area of the Australian continent (Murray Darling Basin Authority 2022) (Figure 5.1).

Pardoe (1995:696) has argued for a 'punctuation in Aboriginal demographic, social and biological organisation' within societies located in the MDB, with greatest 'archaeological visibility' after about 7000 cal BP. This was a significant occurrence, contained within the trajectory of environmental change associated with the terminal Pleistocene from 18,000 cal BP and the continuing evolution of the modern river system (Pardoe 1995:696–699; Gill 1973:1–97). However, Westell et al. (2020:171) argued that the modern river system transitioned earlier at around 15,000 cal BP based on dating evidence of intensive shell midden formation at the Pike River in the South Australian Riverland region (see also Garvey 2017:94).

The modern river system evolved from an environmental transition which extended from 25,000 cal BP, constituting a transformation from seasonally fast flowing and high discharge rivers originating in the Great Dividing Range. Such rivers were dangerous, colder and bigger than modern versions. Human activity, during the period 50–30 ka, was largely restricted to lake systems such as at Willandra and Menindee and the edges of the Murray River floodplain (Pardoe 1995:699; Westell et al. 2020; Westell 2022).

Modern river systems of the MDB consist of narrow courses, longer river frontages, wide floodplains, associated lake systems and anabranches with considerable micro-environmental variation. This translated into environments with a much higher resource base and consequently much more suitable for human occupation than previous riverine environments in the region (Pardoe 1995:696–701). The subsistence cycle of the modern river system was dominated by the annual flooding regime which replenished resources in accordance with the longer-term wet-dry cycles driven by the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) environmental phenomena as outlined in Chapter four.

Pardoe (1995:702) argued that prior to European invasion and the introduction of European diseases, the MDB was the demographic heartland of south-eastern Australia, with a population density 20–40 times that of non-riverine populations in the same general region. Pardoe (1995:703) noted changes in skeletal morphology amongst MDB populations around 7000 cal BP, constituting a decrease in skull measurements of 7.3% for men and a dental reduction of 4.5% for men and 1.4% in women, respectively. Brown (1987:62) attributed this to adaptation to increasing ambient temperature. Pardoe (1995:703) estimated that this translated to a reduction in body mass of 17% in men and 20% in women but noted that no other episode of climate change had this effect in the past. Pardoe (1995:703) considered and rejected a simple selection model because of the short time frame involved and posited the loss in stature as a likely ‘biocultural’ adaptation. This was argued to have been caused by a mix of demography, disease, seasonal famine, territoriality, violent trauma, biology of group relations and the possible effect of predator-prey interaction through the loss of most

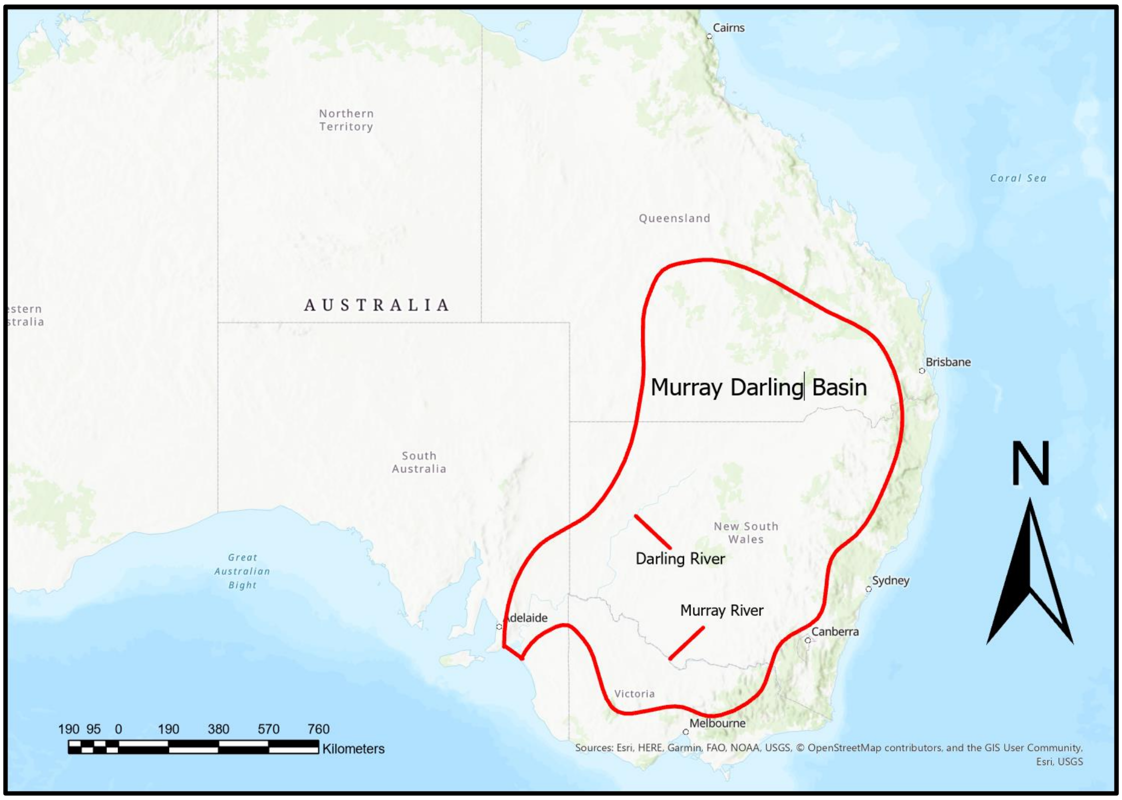


Figure 5.1: Murray Darling Basin.

mammals over the size of 100 kg, in a prior megafaunal extinction (Pardoe 1988, 1990, 1994, 1995:703–704).

The regional transformation of the populations of the MDB in a comparatively short time, as described by Pardoe, is a potential example of developmental processes, such as outlined by Smith (2015:229), where an adaptive niche was constructed within riverine floodplain environments in response to external influences and was potentially expressed as morphological changes within the human, plant and animal populations involved.

Societies were differentiated from non-riverine neighbours by a relatively stable and rich resource base, high population density, exclusive social behaviours, endogamous kinship relations, distinct biological grouping and high territoriality as indicated by the presence of cemeteries (Pardoe 1998, 2003:49). This cultural and economic niche was based on the intensive exploitation of aquatic and terrestrial plants, fish, freshwater mussels, crustaceans, birds and animals and governed by seasonal flooding following the spring melt in the Great Dividing Range (Pardoe 1995:708–709; see also Jones 2016; Jones et al. 2017). Within this dynamic system, the presence of earth mounds dating from ~5000 cal BP is a potential indicator of the broadening of diets in some sub-regions of the MDB from this time because of:

- Evidence of the repeated use of earth ovens in specific locations near billabongs and anabranch creeks (Coutts et al. 1976,1977,1980); Jones 2016; Jones et al. 2017, 2022; Klaver 1998, Martin 2006);
- The seasonal availability of significant quantities of aquatic plants for carbohydrate and fibre, likely supported by active management of plant resources by fire and active manipulation (Gott 1982; Jones 2016; Jones et al. 2017, 2022; Klaver 1998, Martin 2006); and,
- Dental evidence on skeletal material has indicated damage due to fibre processing and a diet high in abrasive material potentially originating from the intensive use of earth ovens and the inclusion of burnt clay particles and ash in cooked items (Pardoe 1995:710).

Pardoe (1995:711) produced a developmental model for floodplain populations based on the intimate association of environment, biology and culture, incorporating exclusive territoriality and reproductive isolation with economies partially supported by the seasonal use of heat retainer cooking technology and the active management of a set of diverse resources. For a wider discussion of continental perspectives (some controversial) of resource management and innovation by Australian Aboriginal peoples see Gammage (2011), Gerritsen (2008), Pascoe (2014), Rowley-Conwy and Layton (2011:850–851) and Sutton and Walshe (2021).

5.2 Northern Australia

In the tropical north, including the Northern Territory and northern Cape York where mounds are found, high population densities were restricted to coastal landscapes containing river systems which were recharged annually through monsoonal rains (Pardoe 1995:702–703; see also Brockwell 2001b, 2006, 2009). The northern and western coastal environments of the Northern Territory are dominated by numerous river and creek systems that flow to the west of the Litchfield area and north of Arnhem Land traversing through coastal plains, floodplains and estuaries into the Beagle and van Diemen Gulfs (Figure 5.2a, b). These include the Reynolds River in the Litchfield area, East Alligator, West

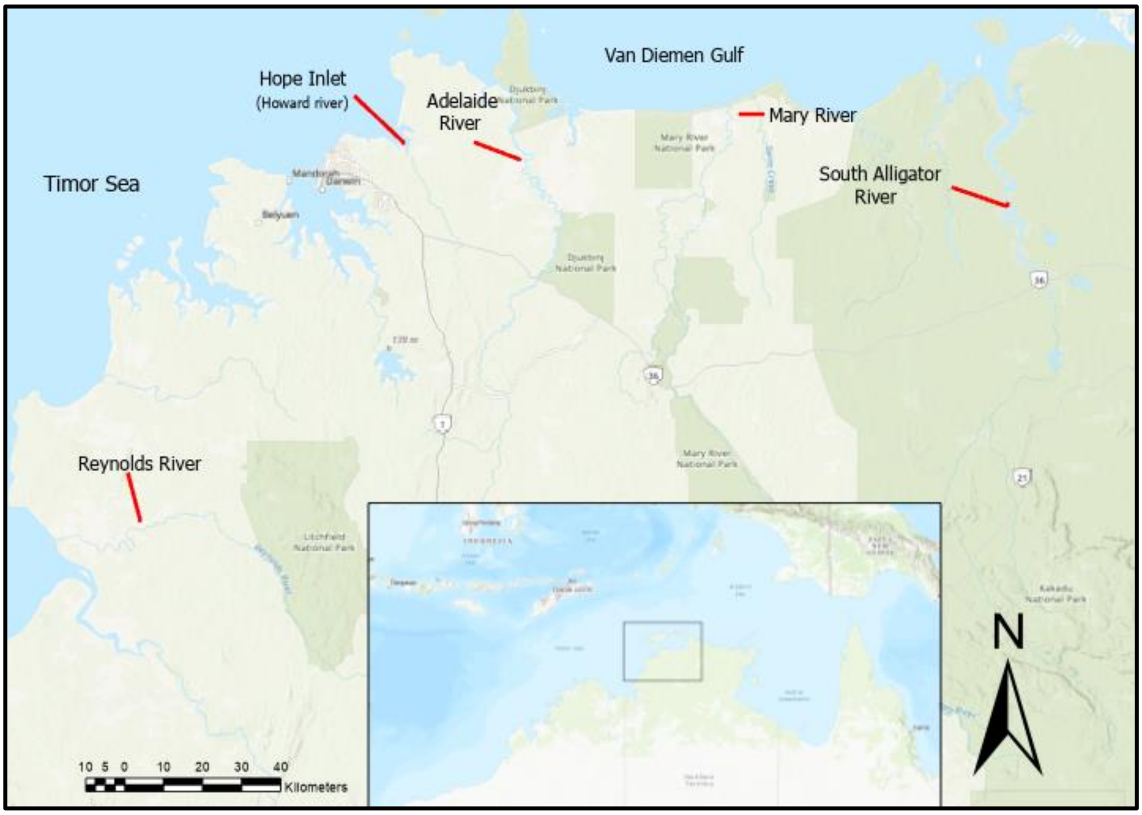


Figure 5.2a: Major rivers which flow into the Timor Sea and western end of the Van Diemen Gulf (Brockwell 2001a, b after Woodroffe et al. 1986, 1993a, 1993b).

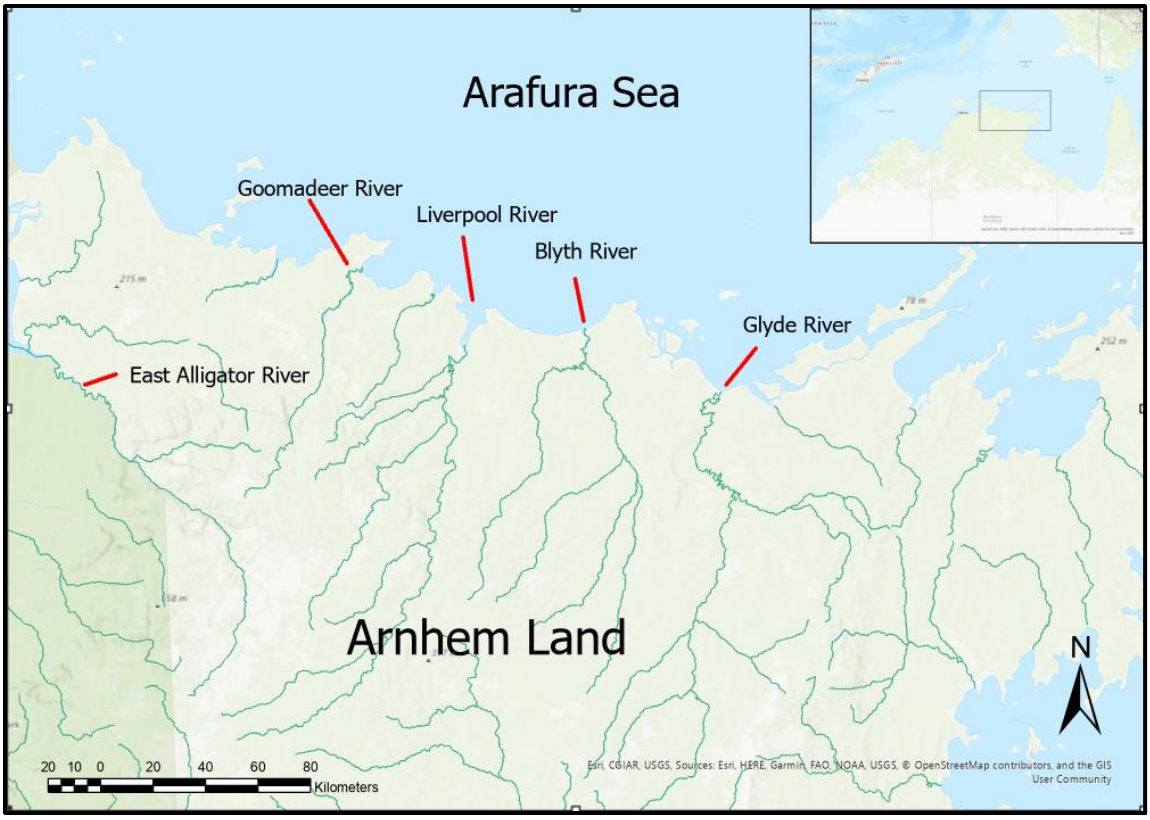


Figure 5.2b: Major rivers which flow from the Arnhem Land escarpment into the Arafura Sea.

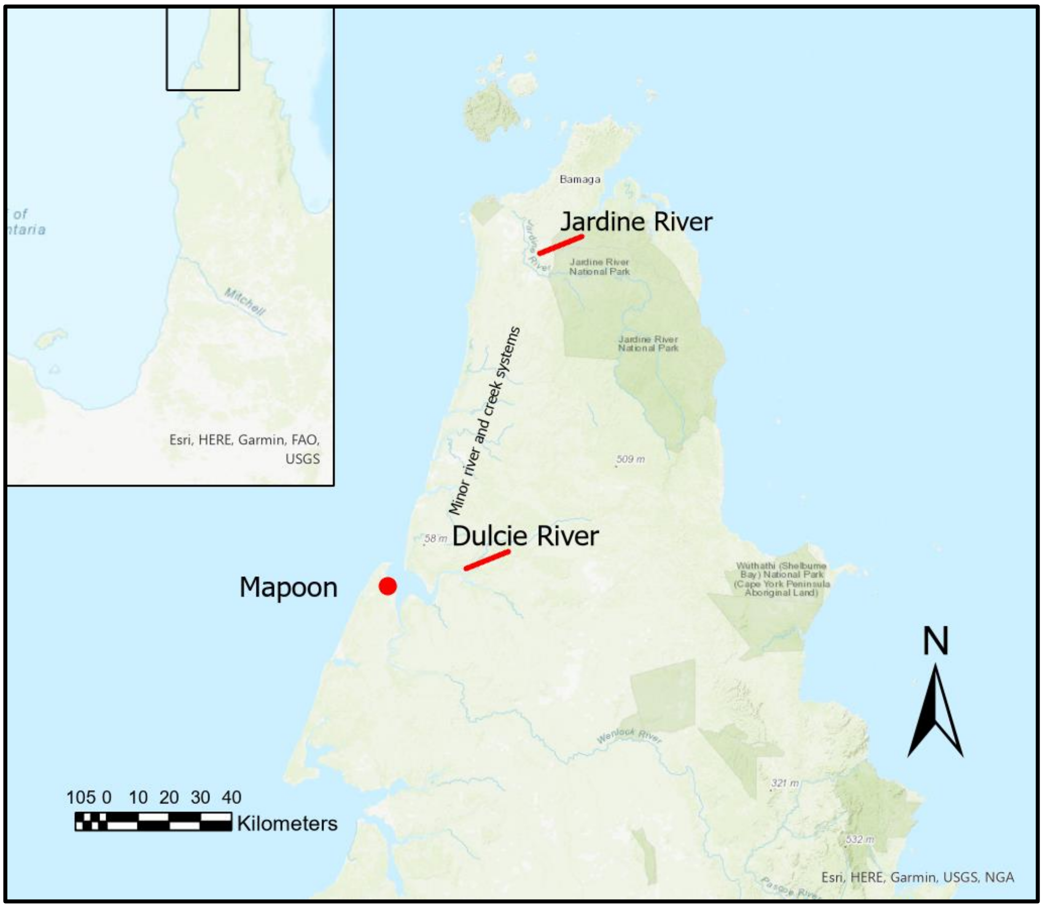


Figure 5.3a: Map of north-western Cape York showing the major rivers flowing west (Brockwell 2001; 2001b:204; Frith and Frith 1995; Haberle and David 2004) .

Figure 5.3b: Westward flowing rivers in western-central Cape York(Brockwell 2001; 2001b:204; Frith and Frith 1995; Haberle and David 2004).

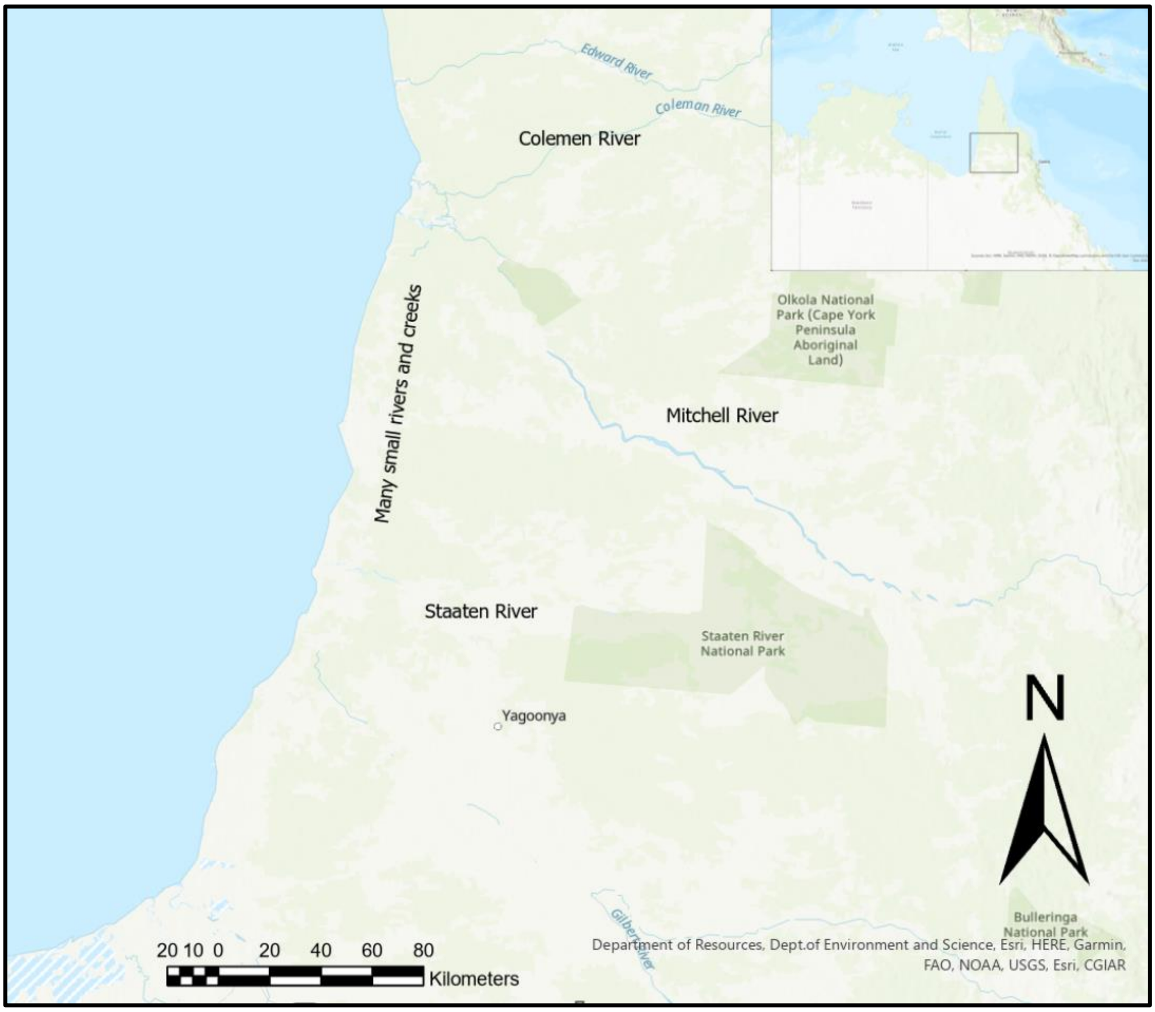


Figure 5.3c: Westward flowing rivers in south-western Cape York (Brockwell 2001; 2001b:204; Frith and Frith 1995; Haberle and David 2004).

Alligator, South Alligator, Mary, Adelaide, Goomadeer, Glyde, Liverpool and Blyth Rivers in Arnhem Land. Similarly, a number of creeks and major rivers flow from Cape York into the eastern Gulf of Carpentaria (Brockwell 2001a:327, 2001b:204; Frith and Frith 1995; Haberle and David 2004), including the Mitchell, Staaten, Coleman, Edward, Holroyd, Archer, Wenlock, Dulcie and Jardine rivers in western Cape York (Figures 5.3a-c). The floodplains comprise three geomorphological units: coastal, estuarine and alluvial plains. The weather cycle comprises a wet and dry season with maximum build-up of ground water from the onset of the wet, with greatest run-off prior to the start of the dry (Brockwell 2001a, b). The floodplains of all river systems formed through similar processes in the mid Holocene but display considerable diversity in their current form and past formation processes (Brockwell 2001a:328–329; Frith and Frith 1995). Table 3.4 provides a comparison of the modern characteristics of the main Arnhem Land catchments and swamp systems. In northern

Australia, occupation sites dating back well into the Pleistocene have been found in numerous rock shelter environments (Clarkson et al. 2017; Brockwell 2001; Haberle and David 2004). The emergence of wetland environments and the stabilisation of sea levels around the mid Holocene saw intensive exploitation of both coastal and freshwater environments demonstrated by numerous radiocarbon dates and sites including shell and earth mounds and open artefact scatters, (Brockwell 2001a, b, 2005, 2006a, b, Brockwell et al. 2017; Shiner and Morrison 2009; 'O Foghl'u 2017, 2021; 'O Foghl'u et al. 2016).

Paleo-environmental reconstructions of the riverine systems flowing into Van Diemen Gulf (Figure 5.2a) have provided a detailed model for the transformations which occurred from the terminal Pleistocene (Woodroffe et al. 1986, 1988; Hiscock and Kershaw 1992; Hiscock 2008). The transformation has been partitioned into a three-phase process. The first was the 'transgressive' phase which occurred from 9000 cal BP with a rise in sea level. This led to the 'big swamp' phase which led to the growth of extensive mangrove stands through continued sea level rise and the accumulation of sediment in estuaries (Hiscock 2008:172). By 4500 cal BP the swamp phase had retreated with replacement of mangroves by sedges and grasses which was termed the 'transition' phase (Brockwell 2001a:53, b; Hiscock 2008:173). During this process populations exploited resources associated with a changing mosaic of environments which emerged and changed on a seasonal basis (Hiscock 1999:91–103). People moved as necessary in accordance with this cycle to access their subsistence needs. Intensive exploitation of coastal resources occurred along northern coasts for a limited time in the late Holocene until 600 cal BP, when continuing evolution of the coastal environment ended the abundance of molluscs (Hiscock 2008:175–179). In her study of the Adelaide River region, Brockwell (2001b:55, 2009) included the period 2000–150 cal BP as a 'freshwater phase' which resulted from ponding behind the seaward chenier creating freshwater flood plains. This was demonstrated by the appearance of freshwater faunal remains in the archaeological record, indicating changes in local settlement strategies, widespread exploitation of wetland resources and the appearance of earth mounds along floodplain margins at this time (Brockwell 2001b:62, 2009). Earth mounds provide the main evidence for floodplain occupation, with Brockwell recording 31 earth mounds in the survey area. The oldest, located in the South Alligator River region, dated to 4726 cal BP (ANU-3992), indicating that the practice of repeated use of heat retainer technology, which result in the formation of earth mounds, extended at least from the mid Holocene in this region (Brockwell 2001b:82, 201, 2009; Woodroffe et al. 1988).

Brockwell's (2001b:89, 2009) study of the Adelaide River region indicates a highly productive and predictable seasonal resource base during the late Holocene freshwater phase. High productivity during the dry season would be a function of accessibility as much as availability and concentration. During the wet season resources would be abundant but dispersed and inaccessible (Brockwell 2001b:89, 2009). While not extensive, this included 65 species of bird, 14 species of reptile, six important fish species, a species of freshwater mussel and nine plant species (Brockwell 2001a:329–330). The abundance of subsistence resources is directly related to a seasonal cycle which incorporated a flooding regime with similarities to that experienced within the MDB. The key differences being the source of the water—immediate and direct local application through rain (in the north) rather than arriving by river (in the southeast). In the MDB, the water largely originates as rainfall or snow which fell on the Great Dividing Range (GDR) on its eastern extremity (western watershed of the GDR) then flowed to the west through regions of increasing aridity.

In the north, settlement strategies would have likely varied according to the season, with access to the floodplain during the dry and retreat with the onset of the wet (Brockwell 2001b:89–90, 2009). Watercraft would have mitigated risk during the periods of transition between seasons (Brockwell 2001b:184, 2009). Brockwell (2001b) cites a number of sources to suggest that this annual sequence is typical of other regions in northern Australia, these include Beck (1986), Cahill (1916), Chaloupka (1981), Chaloupka and Guiliani (1984), McLaughlin (1982), Meehan (1988, 1991), Peterson (1973) and Thomson (1939a, c). Brockwell (2001b:170) interprets earth mounds as occupation sites active during the late wet/early to mid-dry seasons which were seasonally linked to the annual availability of resources. Foelsche (1882:12–14) provided an early account of wetland resources which were exploited by local populations, including fish, geese, ducks, turtles, crocodiles and crocodile eggs, shellfish as well as the roots of waterlilies and rushes (likely *Elocaris dulcis*) (see also Brockwell 2001b:183, 2009). The archaeological record indicates that during the 'late freshwater' phase, activity increased at earth mound sites potentially indicating prolonged occupation, higher frequency of use or that more people were involved, suggesting a socio-economic intensification occurred at this time, potentially indicating a broadening of diets (Brockwell 2001b:171, 2009). Similarly, in their examination of the archaeological record of south-eastern Cape York, Haberle and David (2004:170) concluded:

> During the Holocene, the onset of wet conditions was accompanied by more people moving across the landscape, creating and using more sites in the process.
>
> [And],
>
> …changed settlement systems as more or less stable populations moved residence more frequently; and (are an indication) that socio-demographic conditions and people-land relations–population numbers and/or residential structures–were changing.

In addition, Haberle and David (2004:177) also concluded that there:

> …is evidence for a late broad-spectrum revolution in mainland Australia during the late Holocene.

Haberle and David (2004:177) attributed this broadening of diet equally to climatic and environmental influences and to 'social agency' in the context of choices that are available to individuals and groups. These choices likely included toxic nut processing, large-scale exploitation of the marine mollusc *Tegillarca granosa*, and the extensive use of heat retainer cooking technology demonstrated by the appearance of high numbers of earth mounds in wetland environments across the Australian tropical zone (Haberle and David 2004:177; see also Brockwell 2001a, b, 2005, 2006; Brockwell et al. 2017; Guse 2005:90, 97–106; Morrison 2010, 2013; Morrison et al 2015; 'O Foghl'u 2017, 2021; 'O Foghl'u et al. 2016; Shiner and Morrison 2009). Such production strategies potentially demonstrate cultural and technical innovation and socio-economic reorganisation evidenced by a transition in subsistence procurement in some locations associated with the strategies outlined above.

5.3 Chapter summary

The hydraulic history of the floodplains in both the northern and south-eastern regions of Australia which contain earth mounds are obviously diverse but, interestingly, all show a transition during the late Pleistocene-mid Holocene period characterised by fluctuations in resource types and availability. It seems not inconsequential that two broad regions with vastly different climatic and ecological characteristics developed similar innovative settlement and resource processing strategies, and consequently earth mounds as a socio-economic adaptation, in a similar timeframe from the mid Holocene.

This study focusses on a sub-regional sample of Aboriginal earth mounds for the investigation of intensification theory and a consideration of the introduction of BSD in Australia from the mid Holocene. Aboriginal earth mounds provide an opportunity to investigate such socio-economic change following the Pleistocene-Holocene transition in Australia. In particular, their appearance during the mid Holocene in northern and south-eastern Australia floodplain contexts at about the same time suggests some Aboriginal societies living in wetland environments responded to external influences in similar and innovative ways. The archaeology is often difficult to interpret, and in many cases reliant on proxy data rather than archaeologically derived information. Changes in body size from about 7000 cal BP in Aboriginal groups living in the MDB, and the introduction of higher percentages of carbohydrate into diets reflected in changes to subsistence systems all suggest a combination of environmental, cultural and socio-economic influences at work. Surprisingly, to date no research has been directed at the detailed analysis of Aboriginal earth mound contents in relation to trajectories of economic and social intensification and the emergence of BSD in Australia from the mid Holocene. Such mounds are a significant archaeological feature in many diverse floodplain environments in this continent. In the MDB, earth mounds, and the heat retaining technology which they contain, are ethno-historically and archaeologically associated with the potential emergence of intensive processing of aquatic plant rhizomes from at least 5000 cal BP, and consequently provide circumstantial evidence of the diversification of diets within some floodplain environments around this time (Jones 2016; Jones et al. 2017; Jones et al. 2022; Martin 2006; Pardoe 1995; Westell and Wood 2014). Their concentration around and along bodies of water in flood prone locations also suggests an intensive but seasonal relationship with aquatic resources that are suited to processing in earth ovens. In northern Australia earth mounds are associated with the margins of freshwater floodplains adjacent to bodies of water and the junction of different resource zones. Again, this suggests a concentration of intensive cooking/processing activity in these locations, in response to the local concentration of a wide range of seasonal resources including plant foods.

This review indicates that the earth mounds of the MDB and northern Australia occur in diverse environments. These include the mobile riverine environments of the Darling, Murray, Murrumbidgee and Macquarie River floodplains; the seasonal wetlands of the north Adelaide Plains, some western districts of Victoria, the lacustrine and riverine environments of the Hay Plain and estuarine/freshwater floodplains of the northern tropical regions of the Northern Territory and western Cape York. In respect to developmental processes, structure, morphology and function, earth mounds exhibit strong similarities within sub-regions but considerable diversity across the major continental precincts. Ecological diversity, significant variations in earth mound morphology and contents, and likely differences in levels of physical stress and other pathologies in populations across regions, during the mid to late Holocene, suggests local adaptative nuances in response to differences in local geomorphic and climatic conditions. This probably reflects differences in social organisation, population growth and social trajectories in different places (Hiscock and Sterelny 2023; Ulm 2013). For this reason, earth mounds may provide a local palimpsest of information and a potential opportunity to add to the debates examined above through a comparative analysis of the contents of similar features in different ecological regions. The overview and intensive debate provided by the literature to date is reasonably robust for some regions, but gaps remain and the potential for further research exists, particularly in the southwestern areas of the MDB. The wide range of freshwater environments, including ephemeral lakes, anabranch creeks and billabongs at Calperum provides a morphological and chronological diversity of landscape structures with high potential to add to current knowledge and the debates outlined previously.

Chapter Six: Methods

6.1 Introduction

6.1.1 Overview

Previous chapters have reviewed Australian earth mound research literature, regional setting and theoretical models relevant to this investigation into Aboriginal earth mounds at Calperum Station, in the South Australian Riverland. This chapter outlines the methods used to further this investigation into the potential relationship of mounds in this region to socio-economic intensification and broadening of diets from the mid Holocene.

To date > 55 mound features have been identified on the floodplain at Calperum through pedestrian surveys conducted over a series of field seasons from 2015 through 2019 (Jones 2016; Jones et al. 2017; Jones et al. 2022; Westell et al. 2020). The field work for this study involved the excavation of six single 0.5 m by 0.5 m test pits in six mounds which were selected to sample a variety of landscape contexts across the Calperum floodplain. Excavations were followed by a program of radiocarbon dating and an analysis of mound contents and sediments. Radiocarbon dating was conducted at the Australian Nuclear Science and Technology Organisation (ANSTO) and University of Waikato Radiocarbon Dating Laboratory. External analysis was supported by three ANSTO grants (AP12393, AP12957 and AP12533) and student grants provided by the Australian Archaeological Association Student Research Grant Scheme and the Royal Society of South Australia. Fieldwork was supported by an ARC Linkage grant (LP170100479).

Prior to the commencement of fieldwork for this project, a review of suitable analytical methods was conducted and methods which were potentially suitable, available and likely to assist in addressing the research questions and objectives listed in Chapter One, were shortlisted. Associate Professor Michael Morrison provided a number of earth mound samples from the Weipa region for a program of pilot studies to determine the suitability of three methods not previously reported in this context for the analysis of sediments (see Appendices One and Two for a summary of the outcomes of these earlier studies). The latter included Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR) and phytolith, starch and pollen (plant microfossil) morphology.

Magnetic susceptibility (MS) had been previously used in Australia in archaeological studies of a rock shelter in northern Queensland and earth mounds in both the MDB and northern Australia to assess questions of human settlement and site use (Lowe et al. 2016; Martin 2006; Ó Foghlú 2021; Sullivan and Buchan 1980). MS and plant microfossil morphology were included in the pilot study for assessment and familiarisation purposes. SEM and FTIR were not selected for further use due to issues with access and cost (SEM) and low resolution (FTIR) (see Appendix One). Microfossil analysis was included following a successful trial.

Additional techniques with known suitability for sediment analysis, loss on ignition (LOI), sediment grain size, portable x-ray fluorescence (pXRF) and inductively coupled plasma mass spectroscopy (ICP-MS) were not trialled prior to the excavation of the Calperum mounds due to a lack of access and equipment at that time. Access to equipment to address this lack became available shortly after the Calperum excavations were completed. Radiocarbon dating was adopted to provide estimates of mound ages via samples of shell and charcoal.

The techniques listed above were selected for their potential to address the second and third research aims listed in chapter one, these were:

> To investigate the composition (macro and micro) of earth mounds located on the Calperum floodplain including faunal and botanical remains, artefacts, sediments and trends over time.
>
> To establish and investigate the chronological context of earth mounds on the Calperum floodplain and to compare the results to published chronological, environmental and climatic data from the mid to late-Holocene.

These methods potentially provide insights into mound formation processes and disturbance as well as changes in resource exploitation and landscape use—a similar approach was employed by Lowe et al. (2016) in their integrated study of sediments excavated from rock shelters in northern Australia. Variation in grain size profiles and LOI percentages in archaeological sediments, can provide insights into site formation processes and/or subsequent sediment disturbance (French 2015; Lowe et al. 2018). MS analysis allows for the detection of magnetic minerals in sediments (Evans and Heller 2003), the identification of which can indicate both cultural and natural phenomena, including pedogenesis, chemical weathering and/or burning (Dalan and Banjeree 1998). Elemental profiling of sediments using pXRF and ICP-MS for the quantification of P, Ca and other elements can potentially identify trends induced by anthropogenic activity (French 2015:34–

39). Plant microfossil analysis can provide insights into past environmental conditions such as water availability and the presence, or otherwise, of important food species. In addition to the use of MS for sediment analysis, a gradiometer was used to prospect for evidence of subsurface hearth features in the vicinity of mound HIS_2_23 to assess the possibility of Aboriginal residential activity close to a mound location.

6.1.2 Ethics and community engagement

The project received Flinders University Human Research Ethic Committee approval (No. 6618) and a South Australian government permit (Ref: B423901) for the excavations and scientific analysis. River Murray and Mallee Aboriginal Corporation (RMMAC) members were involved in all field work and approved all excavation methods and locations. During field work, a pre-start briefing on the activities planned for the day was provided to the RMMAC members present. Each day a debrief and cultural smoking practices were conducted to conclude the day's activities in accordance with cultural protocols. In addition, progress reports were provided to RMMAC members through presentations at board meetings convened in the Riverland region during the field and laboratory components of this research. This final version of the thesis has also been endorsed by RMMAC directors.

6.2 Methods

6.2.1 Survey

The key activities adopted for this study included exploratory pedestrian surveys over the period 2018–2021 to identify earth mounds at Calperum (see Appendix Three), the identification of suitable mounds for excavation (including the use of aerial survey) and the analysis of contents and sediments, as outlined below. Mounds were selected on the basis of differences in surface morphology (e. g. ashy, sealed or eroded) and relationship to various floodplain contexts (e. g. anabranch creeks, billabongs and lagoons) (Figure 6.1a, b, c). A real time kinetic device (Leica Icon GS16) was used to record mound elevation profiles as part of this survey (Figures 6.1a, b, c). The field survey component added to the mound data recorded over 2015–2017 as part of a previous study (Jones 2016; Jones et al. 2017).

6.2.2 Calperum excavations

The excavation, sampling and recording of six mounds for ^{14}C dating, contents and sediments analyses occurred in September and October 2019 and September 2020 (see Appendix Seven for samples of field documentation). A floodplain auger sample for comparison with earth mound sediments was taken in April 2021. The analyses of field samples were conducted in the Flinders University Archaeological Research Laboratory, Australian Nuclear Science and Technology Organisation (ANSTO), University of Waikato Radiocarbon Dating Laboratory and the Paleo Research Institute of Golden, Colorado, over 2020–2022.

This research focussed on the analysis of mound sediments and contents. The latter potentially providing cultural material, faunal and plant remains. In their experimental investigation of the temperature profiles within earth ovens Thoms et al. (2015:270–271, 272–277) indicated that the temperature of the food cooked rarely reached 100°C and moisture was retained in food and plant packing material. Thus, indicating the possibility that evidence of plant material could survive in mound sediments, which could provide information regarding the presence and relative importance of specific plant species which have been targeted by Aboriginal people in the past. In this context, plant imprints in clay heat retainer nodules were reported from the excavation of mounds near Balranald, NSW by Martin (2006), and consequently a range of larger heat retainer nodules obtained during each excavation at Calperum were examined in the laboratory for imprints and unusual markings using light microscopy (10x).

Excavation at each of the mound sites consisted of a single square pit measuring 0.5 m x 0.5 m (e. g., figure 6.3) which was located to sample the deepest point of the mound. As a consequence of intensive mixing during mound formation and the operation of ground ovens a single stratigraphic context was applied, and excavation proceeded in 5 mm spits. A Leica TS16 robotic total station referenced to three known datums (obtained with RTK GPS) was used to provide spatial coordinates of starting elevations for each 5 cm spit and finds of particular interest during excavation.

Each pit was marked using string and metal pegs. Hand tools used included secateurs (for root removal), a margin trowel, brushes and dust pan. Proforma context, trench and excavation unit documents were used to record all relevant details of the excavation and sampling, including photographs of the start of each level, soil colour (Munsell code), pH, artefacts, faunal material and other cultural material (Appendix Six). A section drawing of each pit wall was completed at the conclusion of each excavation. All materials will be repatriated to the site at the conclusion of analyses, in accordance with RMMAC wishes.

Pits were excavated in 5 cm excavation units (XUs) with all excavated material sieved on site through nested 1 mm and 3 mm sieves (mounds HIS_2_21, HIS_2_22, HIS_2_23, RRWWS3) or 3 mm and 7 mm sieves (a 1 mm sieve was unavailable in this instance) (HCN20, HCN21). All material captured in the sieves was retained for analysis together with a 1 kg sample of sieved sediment from each XU. Column samples of undisturbed sediment were also taken from one side of each excavation pit. Shell and charcoal samples for ^{14}C dating were taken in situ using steel tweezers and/or a steel trowel and wrapped in aluminium foil prior to double bagging in zip-lock plastic bags. Radiocarbon samples were later weighed at the Flinders University Archaeological Research Laboratory using digital scales prior to dispatch for analysis.

6.2.3 Contents analyses

The mounds on the Calperum floodplain are generally comprised of a mixture of fine grained sediments, nodules of clay heat retainers, charcoal, shell fragments, unburnt clay, and root material from living and dead plants. Organic root material was separated from soil and mineral components for further examination using flotation equipment. The flotation equipment comprised a raised water tank (tank one) with a 1 mm sieve mounted at the bottom level of an overflow outlet. Mound samples were added to the sieve in the first tank while water flowed through the outlet conveying floating material onto a 2 mm sieve mounted to a lower holding tank (tank two). This second tank contained a submersible pump which continuously returned the water to an inlet located below the sieve in the first tank. Heavier material greater than 1 mm in size was retained on flexible plastic 1 mm mesh placed on sieve one prior to use, then dried for examination. Fine sediments which passed through the first sieve and root material recovered on sieve 2 were dried and weighed, then examined for items of interest (such as light charcoal pieces in the latter case).

The surfaces of all clay heat retainer nodules retained during field sieving were examined for any imprints and marks related to their manufacture, with particular emphasis on the identification of imprints related to the use of plants. The sieved fractions from each mound level were placed in sorting trays and physically examined in the laboratory to identify any faunal, macro-botanical and artefactual materials, sorted into material classes using a magnifying lamp device (Figure 6.2).

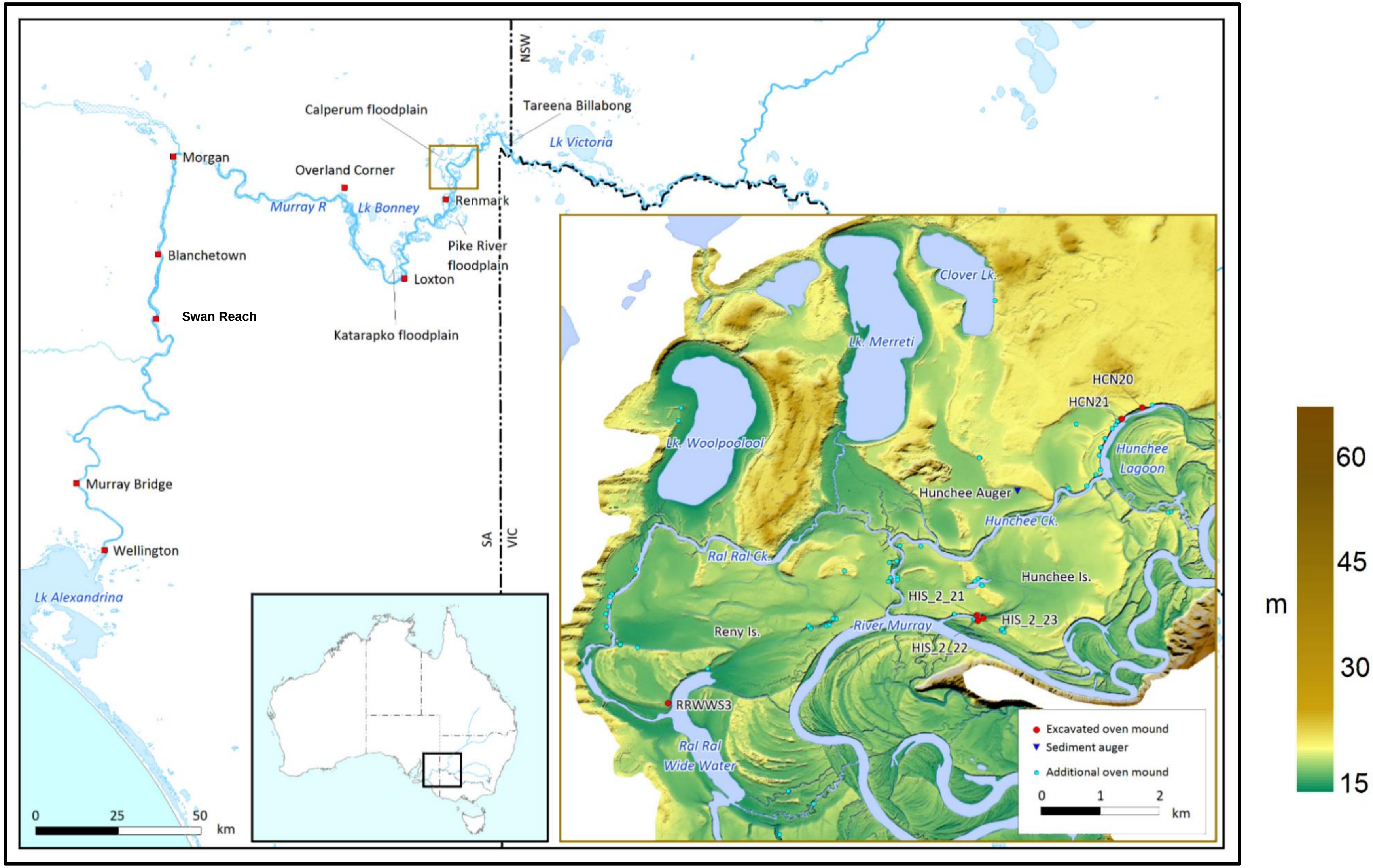
Stone artefacts and other material of interest found in mound sediments were retrieved and placed in zip-lock bags for later weighing with digital scales, photography and description. Bags were labelled with date, site, SU and XU number, material recovered and sieve size. Specimens were photographed with a digital camera in the Flinders Archaeology Photography Laboratory (see Appendix six). The co-ordinates, photographs and details of artefacts located in close association with but not within mounds HIS_2_21, HIS_2_22 and HIS_2_23 were recorded in the field. The purpose of the surface investigation was to provide an indicative sample for comparison with previous studies of lithic materials conducted at Calperum by Incerti (2018) and Thredgold et al. (2017).

Snail shell and bone fragments were retained for analysis and identification where possible. Assistance for the analysis of bone was provided by Dr Diana Fusco of Flinders University Palaeontology and by Mr Peter Hunt and Ms Shirley Sorokin of the South Australian Museum who provided assistance in relation to the confirmation of mollusc identifications.

6.2.4 Sediment analyses

6.2.4.1 Laboratory magnetic susceptibility analyses

Sediment magnetic properties were measured in the laboratory with the Bartington Instruments MS3 device using the MS2B sensor. Sediment samples were weighed prior to testing, the instrument was zeroed between readings and measurement time was 1 second. MS profiles of low frequency, high frequency and frequency dependence were determined as a proxy for anthropogenic burning in order to determine the base of anthropogenically modified sediment in each mound. Low frequency values were graphed to demonstrate variation with depth through the excavations (Dearing et al. 1996; Lowe et al. 2016, 2018; Maher 1986)



6.1a: The study area showing the location of mound sites and topography within the Calperum floodplain. The relief image is based on the Digital Elevation model (DEM) 5 metre Grid of Australia derived from LiDAR © Commonwealth of Australia (Geoscience Australia) 2015 (Jones et al. 2022 – map prepared by C. Westell).

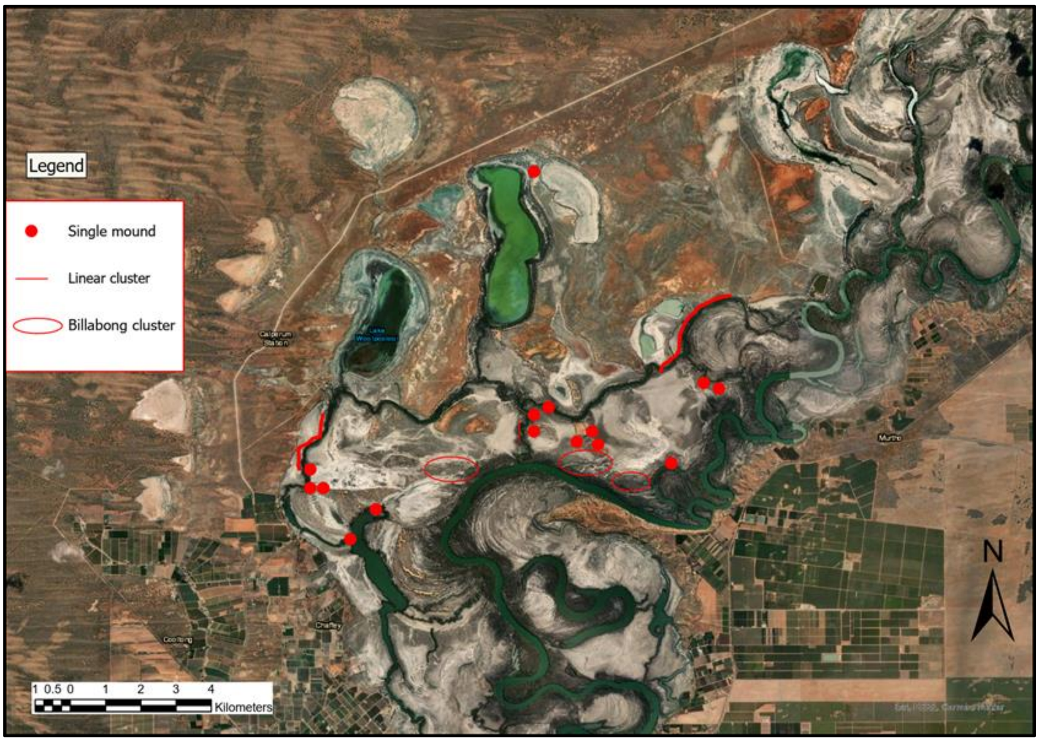


Figure 6.1b: Principal groupings of recorded mounds on the Calperum floodplain.

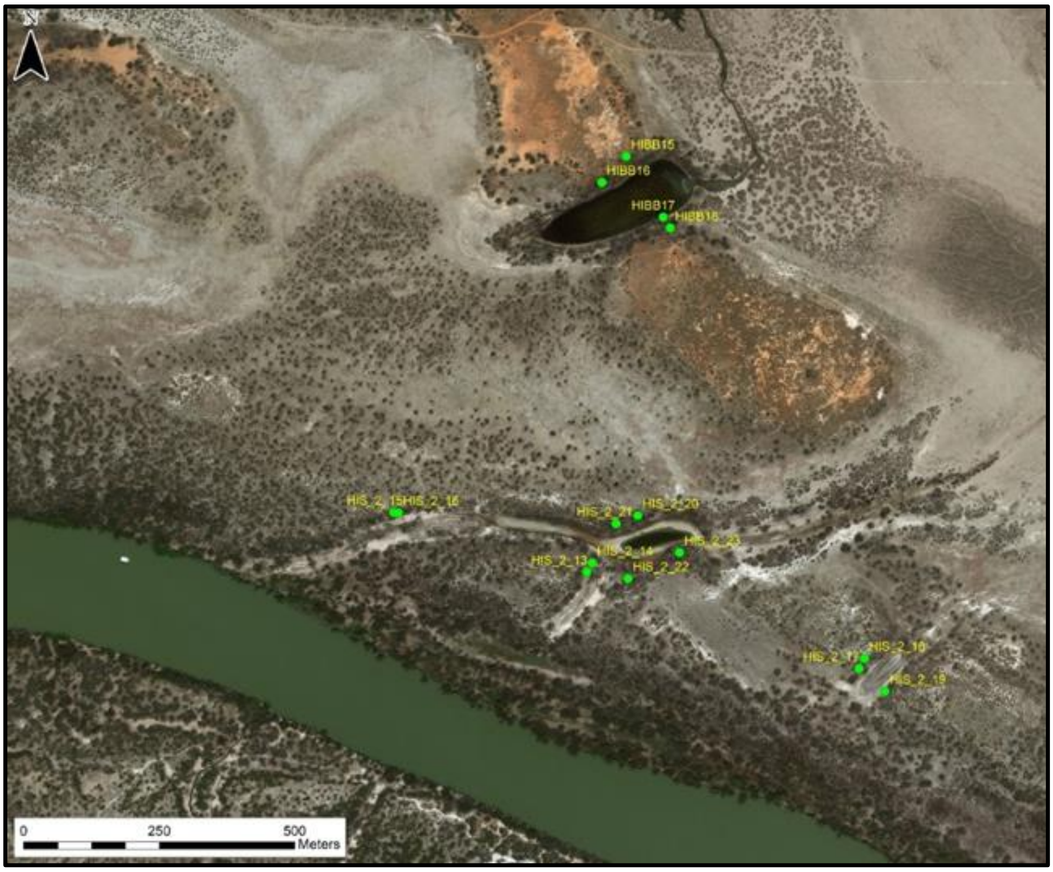


Figure 6.1c: Image showing sand sheets (associated with a billabong derived from a palaeo-channel of the Murray River) located near mound complexes (with individual mounds in green) on Hunchee island. Occupational material including stone scatters and burnt clay indicating hearth remains, was noted on the surface of these sandy features. The main channel of the river is shown at the bottom of the image.

Figure 6.2: View of the Flinders University Archaeological Laboratory with earth mound sediment sorting in the foreground. Photograph R. Jones September 2021.

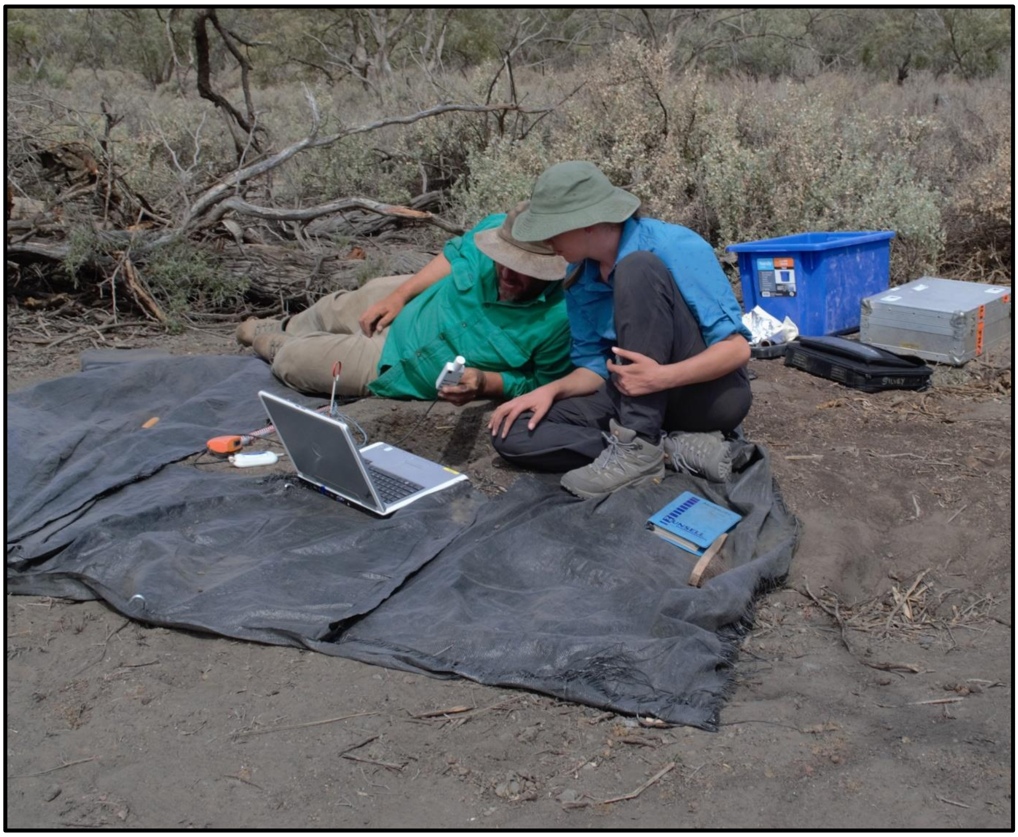


Figure 6.3: Dr Ian Moffat and field volunteer Cassandra Schill conducting MS analysis at mound HIS_2_22. Photograph R. Jones September 2019.

6.2.4.2 Field magnetic susceptibility analyses

Magnetic surveys were limited to mounds HIS_2_21, HIS_2_22, and HIS_2_23 because of time constraints during field work. Stratigraphic investigations were undertaken at 5 cm intervals within the HIS_2_21, HIS_2_22 and HIS_2_23 excavations using the MS2E sensor. Investigations were undertaken on the north wall of HIS_2_21, approximately 10 cm east of the western wall. Investigations were undertaken on the east wall of HIS_2_22. Investigations was undertaken on the south wall of HIS_2_23, approximately 10 cm east of the west wall. The sensor was run in continuous mode for approximately 10 minutes before the first measurement was collected and zeroed in the air before and after each measurements. Each sample and blank was measured for 5 seconds (Figure 6.3).

Surface magnetic susceptibility investigations were undertaken at the HIS_2_22 and HIS_2_23 mounds at 0.5 m spacing using the MS2D sensor. The sensor was run in continuous mode for approximately 10 minutes before the first measurement was collected and zeroed in the air before and after each measurements. Each sample and blank was measured for 1 second.

6.2.4.3 Sediment laboratory analyses

Sieved bulk sediment samples collected from each excavation unit in the field were used for the laboratory analyses described below.

Sediment colour values were determined in the laboratory using artificial light for each XU using Munsell colour charts (in accordance with the Year 2000 Revised Washable Edition pp. 1–4).

Grain size profiles were determined in the laboratory by passing approximately 50 g of sediment through an Endecotts laboratory test sieve pack comprising 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, and 0.063 mm aperture sieves which were vibrated for 5 minutes on an Endecotts Minor vibration device. These sieve fractions were chosen as they correspond to the very coarse sand, coarse sand, medium sand, fine sand, very fine sand and clay/silt grain size in the Wentworth scale (Wentworth 1922). Weights of each fraction were then calculated as a percentage of total retained weight of sediment. Grain size fractions higher than 1 mm were not included in the comparative analysis to exclude potential bias associated with the presence of large pieces of heat retainer and the use of a 3mm sieve for mounds HCN20 and HCN21 for preliminary sieving in the field.

Loss on ignition (LOI) was conducted in two stages on sediments previously dried overnight at 100^{o}C in a programmable Across International CF1200 muffle furnace at 550^{o}C and 1000^{o}C to determine LOI for organic and carbonate materials, respectively. Samples of sediment from each XU were placed in a weighed ceramic crucible (previously dried overnight at 100^{o}C in a Laboratory oven) and weighed. Weight loss was measured after heating the samples overnight at 100^{o}C to remove water, then at 550^{o}C for four hours to remove organic matter and at 1000^{o}C for two hours to remove carbonates. After each heating step the crucibles were allowed to cool completely in the oven or furnace before weighing.

pH values were obtained for each XU using a soil pH meter PH220S-KIT, equipped with a cabled spear tip pH electrode with a measurement time of 0.8 seconds per sample. Calibration was conducted with solutions of pH7 and pH10. pH readings were taken from 20 gm sediment samples moistened with 5 ml of deionised water.

Samples of floodplain sediment were obtained to provide control data and a comparative analysis for the results obtained from the mound sediments outlined above. A Dormer auger with a 50 mm general purpose soil sampler was used to extract sediment samples from a location identified from LiDAR and topographic analysis as a palaeo-river channel 3 km south-west of the Hunchee Creek mound HCN21 (Figure 6.1a, b) (see also Westell 2022:160), which were analysed for radiocarbon dating, grain size, magnetic susceptibility and LOI. The auger samples were taken at depths of 16 cm, 29 cm, 42 cm, 57 cm and 77 cm.

6.2.5 Plant microfossils (see Cummings 2019, 2021—reports attached in Appendix Two)

Plant microfossils were analysed from samples taken across the six excavated Calperum mounds for a comparison of environmental vegetation profiles present. One 800–1000 gm sediment sample was taken from each mound (Table 6.1) for analysis by the Palaeo Research Institute in Golden, Colorado, USA. Plant microfossil analysis was restricted to a single sample from each mound due to limited funding. Levels selected were contained to levels 3–5 except for level 8 of mound HIS_2_22 which was one of three mounds around the Double Thookle Billabong (also known as Hunchee Island South Billabong). The similar morphology of HIS_2_22 and HIS_2_23 potentially indicated a similar age range and consequently the sample for the former was taken from level 8 to test for environmental continuity in addition to the range of radiocarbon determinations outlined below. The analytical methods used were as outlined below.

6.2.5.1 Pollen

The Palaeo Research Institute laboratory used a chemical extraction technique based on flotation for recovering pollen grains from the Calperum sediment samples as outlined in Appendix Two (Cummings 2021). The process was developed for extracting pollen from soils where the ratio of pollen to inorganic material is relatively low. Hydrochloric acid (10%) was used to assess and remove any calcium carbonates present in the sediment samples. The samples were then screened through 250-micron mesh. Multiple water rinses were used to dilute the solution (in accordance with Stoke's Law) with a settling time of 90 minutes. A small quantity of sodium hexametaphosphate was added to the first rinse to suspend clay-sized particles prior to additional rinsing. This process was repeated with ethylenediaminetetraacetic acid (EDTA) to remove clay, soluble organics, and iron and finished with the freeze-drying of samples under vacuum.

After drying, the samples were mixed with sodium polytungstate (SPT), at a density of 1.8 g/ml and centrifuged to separate organic (pollen and starch) from inorganic waste material. The lighter fraction was recovered, and the process repeated as required. The pollen containing organic fraction was rinsed, then treated (25 minutes) with hot hydrofluoric acid to remove any remaining inorganic particles. The samples were then acetylated for 10 minutes to remove any extraneous organic matter before being rinsed with reverse osmosis deionised water (RODI). Drops of potassium hydroxide (KOH) were added to each sample, and the mixture stained lightly with safranin. Further centrifugation, at high speeds for short intervals, was applied to remove any remaining organic debris, to improve microscopy. A light microscope was used to count pollen at a magnification of 500x. Pollen preservation results in these samples varied from good to poor. An extensive comparative reference housed at the PalaeoResearch Institute assisted in pollen identification to the family, genus and species level where possible.

Pollen aggregates were recorded during pollen identification. Aggregates are clumps of a single type of pollen and may be interpreted to represent either pollen dispersal over short distances or the introduction of portions of the plant represented into an archaeological setting. The aggregates were included in the pollen counts as single grains, as per customary practice. An “A” next to pollen frequency on the percentage pollen diagram notes the presence of aggregates.

The percentage pollen diagram was produced using Tilia software Version 2.1.1. Total pollen concentrations were calculated in Tilia using the quantity of sample processed in cubic centimetres (cc), the quantity of exotics (spores) added to the sample, the quantity of exotics counted, and the total pollen counted and expressed as pollen per cubic centimetre of sediment.

Table 6.1: Sampling detail for the plant microfossil analysis of selected Calperum mounds.

Mound Code	Location	Level	Depth cm
HIS_2_21	Hunchee island south billabong levee	3	11–15
HIS_2_22	Hunchee island south billabong levee	8	36–40
HIS_2_23	Hunchee island south billabong levee	4	16–20
RRWWS3	Ral Ral Wide Water billabong levee	3	11–15
HCN20	Hunchee Creek north billabong levee	5	21–25
HCN21	Hunchee Creek north billabong levee	4	16–20

“Indeterminate” pollen includes pollen grains that are folded, mutilated or otherwise distorted beyond recognition. These grains were included in the total pollen count since they are part of the pollen record. The microscopic charcoal frequency registers the relationship between pollen and charcoal. The total number of microscopic charcoal fragments was divided by the pollen sum, resulting in a charcoal frequency that reflects the quantity of microscopic charcoal fragments observed, normalized per 100 pollen grains.

The pollen and phytolith extraction method aims to extract starch granules when they are present. Since starch analysis was requested for these samples, starches were recorded as part of the pollen count, an additional search for starches was conducted. Starch granules are a plant's mechanism for storing carbohydrates. Starches are found in numerous seeds, as well as in starchy roots and tubers. The primary categories of starches include the following: with or without visible hila, hilum centric or eccentric, hila patterns (dot, cracked, elongated) and shape of starch (angular, ellipse, circular, or lenticular). Some of these starch categories are typical of specific plants, while others are more common and tend to occur in many.

6.2.5.2 Phytolith and starch extraction

Extraction to recover both phytoliths and starch grains from sediment samples is based primarily on the heavy liquid technique for pollen extraction outlined above (Cummings 2021). Fifteen ml of sediment from each sample was placed in a beaker with bleach (an oxidant) then left undisturbed overnight. The following day the sample beakers were filled with RODI water and allowed to settle for 90 minutes, after which the supernatant was poured off. This rinse was repeated four times to remove the oxidizing agent. A small quantity of dilute potassium hydroxide (KOH) was added for a short period (to avoid damage to the silica bodies). Repeated rinses were then used to remove dissolved organic material. Clays were removed using sodium hexametaphosphate and a repetition of the Stokes law settling. Following this, the samples were freeze-dried using a vacuum system, and mixed with sodium polytungstate (SPT, density 2.1 g/ml) and centrifuged to separate the phytoliths and starch grain fraction from most of the inorganic silica fraction. The light, phytolith-and starch-rich fraction of each sample was retained and rinsed with RODI water to remove the heavy liquid then rinsed in alcohol to remove any remaining water. Microscope slides were prepared by adding a drop of sample on a slide, allowing it to dry, then the addition of optical immersion oil prior to covering with a cover slip for counting with a light microscope at a magnification of 500x. A percentage and/or frequency diagram was produced using Tilia 2.0 and TGView 2.1.1.

6.2.5.3 Phytoliths

Terms applied to phytoliths in this study use the International Code for Phytolith Nomenclature (ICPN) (Madella et al. 2005). Phytolith reference samples prepared and curated at the PalaeoResearch Institute were consulted when identifying phytoliths recovered in this study.

Phytoliths are silica bodies produced by plants when soluble silica in ground water absorbed by the roots is carried up the plant's vascular system. Evaporation and metabolism of this water results in precipitation of the silica in and around the cellular walls. Phytoliths, which are distinct and decay-resistant plant remains, enter the soil as the plant components die and break down. However, in sediments as found in the Calperum excavations, they are subject to mechanical breakage, erosion, and deterioration. In archaeological contexts, phytolith transportation can occur through animal consumption, human plant gathering or wind/water erosion. Phytoliths produced in roots/tubers deteriorate at the level of those roots/tubers and are not represented on the growing surfaces. This complicates interpretation as phytolith recovery from stratigraphic sediments does not necessarily represent vegetation coeval with that represented by phytoliths produced in leaves or other above ground vegetative components.

The three major types of grass short cell phytoliths include festucoid, chloridoid and panicoid. Smooth elongate phytoliths are discounted from the analysis since all grasses, various other monocot plants, and several dicots produce them. The phytoliths which were tabulated to represent 'total phytoliths' include the grass short-cells, bulliform, trichome, elongate and dicot forms. All other silica and non-silica body recovery frequencies are calculated by dividing the number of each type recovered by the 'total phytoliths'. Festucoid phytoliths are ascribed primarily to the subfamily Pooideae and occur most abundantly in cool, moist climates. They grow well in shady areas and during the cooler months. They are the first grasses to shoot in the spring, go dormant in the summer and grow again in autumn. Brown (1984) notes that festucoid phytoliths are produced in small quantities by nearly all grasses (mostly rondel-type phytoliths, which exhibit an approximately circular shape). Therefore, while these typical phytolith forms are produced by the subfamily Pooideae, they are not exclusive to this subfamily. Trapeziform phytoliths are tabular and may be thin or thick. Their outer margins may be smooth, slightly spiny or sinuate (Cummins 2021; Brown 1984; Madella and Alexandre 2005).

Summer grasses are divided into the group that thrives in dry conditions (chloridoid) and those that grow best in humid conditions or along sources of water (panicoid). Chloridoid saddle phytoliths are produced by the subfamily Chloridoideae, a warm-season grass that grows in arid to semi-arid areas and requires less available soil moisture (Gould and Shaw

1983:120). They thrive in hot and dry summers. Twiss (1987:181) notes that some members of the subfamily Chloridoideae also produce both bilobate (panicoid) and festucoid phytoliths. Also, saddles may be produced in non-chloridoid grasses. Bilobates and polylobates (lobates) are produced mainly by panicoid (tall) grasses, although a few festucoid grasses also produce these forms. Panicoid or tall grasses prefer the warmth of summer and thrive in humid conditions or grow next to creeks, rivers and lakes.

Bulliform phytoliths are produced in grass leaf cells that control leaf rolling in response to drought. These cells often silicify under wet or moist conditions and increase in abundance as the grass leaves age. Trichomes represent silicified hairs, which may occur on the stems, leaves, and the glumes or bran surrounding grass seeds.

6.2.5.4 Other siliceous microfossils

Diatoms and/or sponge spicules were noted. Pennate diatoms are cosmopolitan, occur in many terrestrial and aquatic settings but indicate the presence of some soil moisture. Sponge spicules represent fresh-water sponges. Diatoms are single-celled algae with a siliceous cell wall. They grow in a wide range of aerophilous habitats, including on wet plants and rocks, in damp soils, marshes, wetlands, mudflats, and various standing and flowing aquatic habitats. Often, their silica cells are preserved in sedimentary deposits. Individual taxa have specific growth requirements and preferences with respect to water chemistry. Thus, the presence (and subsequent identification to the species level) of diatoms in paleoenvironmental contexts can provide information about the nature of the local environment, including water chemistry, hydrologic conditions and substrate characteristics. These data, coupled with input about local geology, hydrology, soil characteristics, pollen and phytoliths, provide evidence of the paleoenvironmental setting. In these phytolith samples, diatoms are noted, but not identified beyond the split of “pennate” and “centric” forms. Often, centric diatoms indicate wet conditions, while some of the pennate diatoms are cosmopolitan, occurring nearly everywhere. Both diatoms and sponge spicules can be transported with sediment.

6.2.6 Radiocarbon age determinations

The prior record of age determinations for mounds in the MDB used charcoal as the predominant (n = 85) material used for dating, with both bone (n = 13) and shell (n = 1) considerably less common (Appendix Nine). The dating of mound RRWWS3/CAPRI17_04 indicated a potential anomaly between ages derived from four samples, two of each from charcoal and shell (see results Chapter). The possibility of younger charcoal entering mounds through the ingress of roots into the sediment matrix then burnt as part of the operation of the mound potentially compromises all charcoal derived dates obtained for mounds in the MDB and possibly elsewhere. In planning the initial dating program for earth mounds at Calperum it was decided to concentrate on mussel shell in the first instance with follow up dating on selected mounds (HCN20 and HCN21) with duplicate samples at various levels (see results Chapter).

In total, 31 mound and other samples from the excavations and related features listed above, (Table 6.2, Figures 6.1a, b and 6.5) were analysed by Accelerator Mass Spectrometry (AMS) at the Australian Nuclear Science and Technology Organisation (ANSTO) Centre for Accelerator Science at Lucas Heights (Fink 2004). The initial samples submitted to ANSTO (n = 13) and the University of Waikato Radiocarbon Dating Laboratory (n = 2) were analysed and resulted in a journal publication (see Jones et al. 2022). An additional three samples, comprising one from an isolated and eroded mound located on the western shoreline of Clover Lake (C. Westell pers. comm. 2021) (Figure 3.4, Table 6.2) and two non-site control samples were also analysed. These were processed at the University of Waikato Radiocarbon Dating Laboratory and the graphite analysed at the Keck AMS Radiocarbon Laboratory, University of California, Irvine, also using AMS. A second group of shell and charcoal samples (n = 13) were submitted to ANSTO following the results of the original analysis (Table 6.2).

The methods used for samples analysed at ANSTO are outlined in Hua et al. (2001). Pre-treatment for charcoal involved the acid-alkali-acid washing method using hot hydrochloric acid followed by sodium hydroxide prior to combustion and graphitisation. The shell samples were cleaned by removal of the shell surface using a dental drill, washing in de-ionised water prior to hydrolysis using phosphoric acid. The carbon dioxide was collected and graphitised as described by Hua et al. (2001). The AMS measurements were performed on the Vega 1MV accelerator (Wilcken et al. 2015). Samples were measured to between 0.26% to 0.38%. The ^{14}C measurements were normalised using NBS Oxalic acid I as the primary standard (Mann 1983). Stable carbon isotopic ratios were measured on the graphite targets using a Vario Microcube Elemental Analyser and an IsoPrime Isotope Ratio Mass Spectrometer (EA/IRMS), the $\delta^{13}C$ was used to correct the measured $^{14}C/^{13}C$ values to determine the radiocarbon age. All results are reported as percent modern carbon (pMC) and as conventional radiocarbon ages (yr BP) following the conventions of Stuiver and Polach (1977).

Pre-treatment for shell samples included washing with deionised water, removing associated organic sediments and debris, where present. The material for radiocarbon dating is then crushed/dispersed and repeatedly subjected to HCl etches to eliminate secondary carbonate components.

In the case of thick shells, the surfaces are physically abraded prior to etching until the hard, primary core remains. Calcite recrystallisation was addressed through the removal of 40–85% of the surface of the shell (Geraldine Jacobsen pers. comm. 2023; see also Kirillova et al. 2018). In the case of porous carbonate nodules and caliche, very long exposure times are applied to allow infiltration of the acid. Acid exposure times, concentrations, and number of repetitions are applied according to the individual characteristics of the sample. Surface area of charcoal samples for carbon dating were increased through crushing. Hydrochloric Acid (HCl) was applied repeatedly to ensure the absence of carbonates.

Conventional Radiocarbon Ages (CRAs) were calibrated using the OxCal 4.4 program (Bronk-Ramsey, 2009) applying the SHCal20 atmospheric curve (Hogg et al., 2020). The calibrated age-ranges listed in Table 2 are reported at 95.4% probability. Gillespie et al. (2009) undertook sampling of freshwater mussel shell upstream from Calperum Station on Murray River tributaries (the Murrumbidgee and Darling Rivers) and concluded that no appreciable reservoir effect would occur in MDB samples. Westell et al. (2020:165) concurred with their assessment and further noted that the 'intervening geology dissected by the river is non-carbonate fluvial/alluvial sediments and underlying quartzose sands of the Pliocene Loxton-Parilla Sands' which would limit the entry of older material which would contaminate younger samples.

Table 6.2: Sampling detail for radiocarbon dating (Jones et al. 2022). Ages for mound RRWWS3 and the Hunchee auger samples were obtained through a collaboration with C. Westell.

Site ID	Level	Laboratory code	Sample context	Material	Reference
HIS_2_21	2	0ZZ566	Earth mound depth 5–10 cm	Fragmented Shell	Jones et al. 2022
HIS_2_21	4	0ZZ567	Earth mound depth 15–20 cm	Shell	Jones et al. 2022
HIS_2_21	6	0ZZ568	Earth mound depth 25–30 cm	Shell	Jones et al. 2022
HIS_2_22	2	0ZZ569	Earth mound depth 5–10 cm	Shell	Jones et al. 2022
HIS_2_22	5	0ZZ570	Earth mound depth 20–25 cm	Shell	Jones et al. 2022
HIS_2_22	8	0ZZ571	Earth mound depth 35–40 cm	Shell	Jones et al. 2022
HIS_2_23	2	OZZ572	Earth mound depth 5–10 cm	Shell	Jones et al. 2022
HIS_2_23	5	0ZZ573	Earth mound depth 20–25 cm	Shell	Jones et al. 2022
HIS_2_23	7a	OZAB05	Earth mound depth 30–35 cm	Shell	Jones et al. 2022
RRWWS3	1	0ZZ991	Earth mound depth 0–5 cm	Shell	Jones et al. 2022
RRWWS3	3	0ZZ992	Earth mound depth 10–15 cm	Shell	Jones et al. 2022
RRWWS3	5	0ZZ993	Earth mound depth 20–25 cm	Charcoal	Jones et al. 2022
RRWWS3	7	0ZZ994	Earth mound depth 30–35 cm	Charcoal	Jones et al. 2022
HCN20_04	4	WK52024	Earth mound depth 15–20 cm	Shell	Jones et al. 2022
HCN21_09	9	WK52025	Earth mound depth 40–45 cm	Charcoal/ashy clay	Jones et al. 2022
CAPR17_23	Surface	OZX285	Surface	Shell	C. Westell pers. comm. 2021
Hunchee auger	-	WK53028	Auger hole depth 16 cm	Charcoal	C. Westell pers. comm. 2021
Hunchee auger	-	WK53029	Auger hole depth 57 cm	Charcoal	C. Westell pers. comm. 2021
HCN20	2	OZAN52	Earth mound depth 5–10 cm	shell	NA
HCN20	2	OZAN53	Earth mound depth 5–10 cm	Charcoal	NA
HCN20	4	OZAN54	Earth mound depth 15–20 cm	shell	NA
HCN20	4	OZAN55	Earth mound depth 15–20 cm	Charcoal	NA
HCN20	6	OZAN56	Earth mound depth 25–30 cm	shell	NA
HCN20	6	OZAN57	Earth mound depth 25–30 cm	Charcoal	NA
HCN20	7	OZAN58	Earth mound depth 30–35 cm	Charcoal	NA
HCN21	1	OZAN59	Earth mound depth 0–5 cm	Shell	NA
HCN21	3	OZAN60	Earth mound depth 10–15 cm	Shell	NA
HCN21	3	OZAN61	Earth mound depth 10–15 cm	Charcoal	NA
HCN21	6	OZAN62	Earth mound depth 10–15 cm	Shell	NA
HCN21	6	OZAN63	Earth mound depth 10–15 cm	Charcoal	NA
HCN21	9	OZAN64	Earth mound depth 40–45 cm	Charcoal	NA

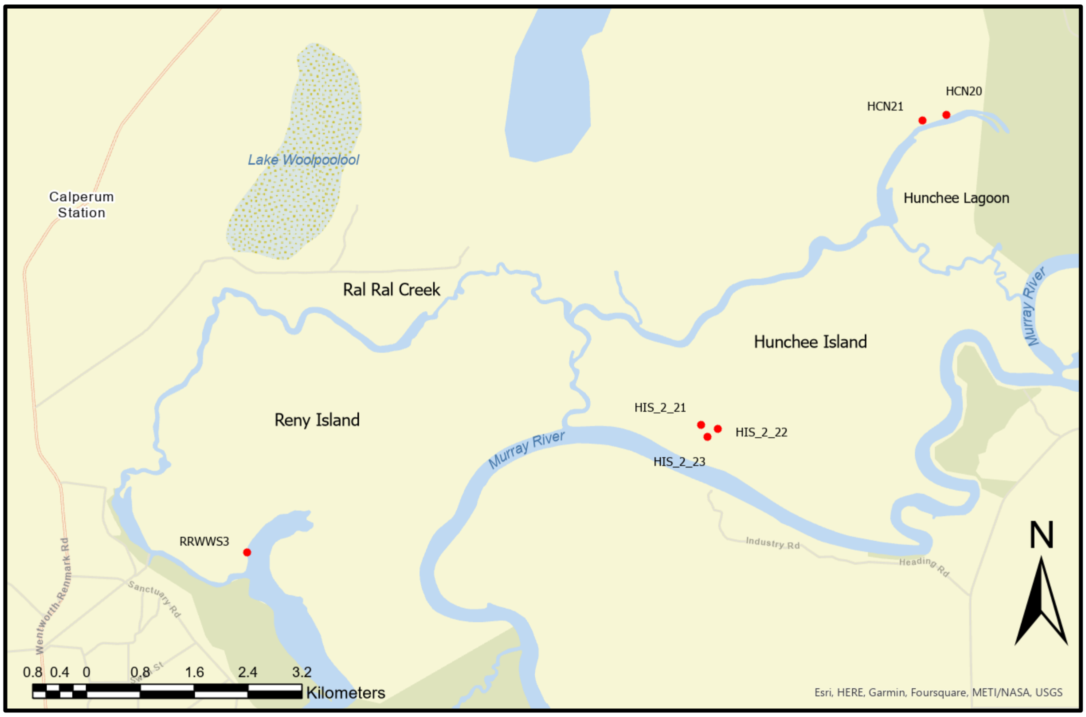


Figure 6.4: Location of earth mounds selected for intensive chronological study.

6.2.7 Elemental analysis

The pXRF method was selected because of availability and ease of use, however the technique was unable to measure elements under atomic number 11 (sodium) which removed the possibility of testing for nitrogen. Also, the method is only semi-quantitative, being subject to issues of precision and accuracy, however, it is considered useful in this context for the identification of trends in the concentration of specific elements associated with anthropogenic and environmental signatures (Frahm 2012a, b; 2013:1091). The principle behind the use of XRF for the quantification of elements present, is the emission (or fluorescence) of a spectrum of X-rays that is specific to that element (Jenkins 1988; Marwick 2005; Norrish and Chappel 1977; Tertian and Claisse 1982). The method has had wide archaeological application for materials such as obsidian, glass, ceramic and metal, and is increasingly used in the analysis of archaeological sediments and minerals (Marwick 2005; Popelka-Filcoff et al. 2007; Popelka-Filcoff et al. 2016; Wallis et al. 2017; Williams et al. 2020).

The ICP-MS method for elemental analysis was included in this study to provide a comparison with the pXRF method to assess the trends apparent in the pXRF data. ICP-MS is a versatile technique widely used in archaeological and environmental investigations. The method is capable of accurately quantifying almost all elements down to extremely low concentrations (French 2015; Golitko and Dussubieux 2016:399–423; Mosely et al. 2014:13). The use of ICP-MS in archaeology includes landscape investigation through the examination of anthropogenic sediments and the direct analysis of artefacts through the use of laser ablation (Dussubieux 2020:5729–5734).

The pXRF instrument used for this analysis was a Bruker Tracer i5 with 2-beam and 30 sec per beam. Calibration was via GeoExplorer 2020. The Bruker device was used to provide an elemental analysis for sediment from each level of the six Calperum excavations to investigate variations in potential anthropological and environmental signatures. Sediment was packed into pXRF cups to a minimum thickness of 10 mm of uncompacted sediment and scanned through 4 µm polyethylene film (Knight et al. 2021). Scanner accuracy was checked several times against the OREAS 45d standard. Variations noted in some elements during calibration is noted in Chapter Seven in consideration of the semi-quantitative nature of this technique. Four elements of interest were selected from the data obtained for a comparative review and consideration of trends both within and across mounds. These were Phosphorus (P), Calcium (Ca), Chloride (Cl), Sodium (Na) and Barium (Ba). P and Ca were selected for their association with processes associated with anthropological activity such as the breakdown of plant material and burning of wood (Cuenca-Garcia 2015). Sodium chloride (common salt) is the indicator for saline ground water and potential periods of salt mobilisation. Barium is a potential indicator for periods of high energy flooding which may influence taphonomic interpretation (Dalai et al. 2002; Wolgemuth and Broecker 1970:375).

The ICP-MS equipment used was a Agilent 8900 ICP-MSMS located at the University of Adelaide (Adelaide Microscopy). Approximately 0.1 g sediment was weighed into ICP tubes. Sample digestion was conducted with aqua regia solution. Centrifuge tubes were emptied into cleaned teflon containers using distilled water to ensure the entire sample was transferred. 3 mL of 12M HCL added to each sample, followed by 1 mL of 12M HNO3. Samples were uncapped at room temp for 16 hours before capping them and placing on a hot plate at 140^{o}C for 2 hours then uncapped and left on a hot plate to evaporate at 100^{o}C. Approximately 5g HCL was added (weight recorded), capped and placed on the hotplate for 1 hour. Samples were transferred into 15mL centrifuge tubes, centrifuged at 3,000 RPM for 12 minutes to separate remaining sediment.

Approximately 1.5 mL were transferred into micro centrifuge tubes and centrifuged at 13,000 RPM for 5 minutes to further separate any fine sediments. Approximately 0.2 g was transferred into ICP tubes (weight recorded) and placed uncapped on the hot plate to evaporate at $80^{o}C$. Approximately 5 g of 2% HNO3 was added to each sample and weight recorded. The samples were then analysed using the ICP-MS equipment.

6.2.8 Geophysical analysis around mound HIS_2_23

A gradiometry survey was conducted in the vicinity of mound HIS_2_23 which was located on the southern side of the Double Thookle Billabong on Hunchee Island (Figures 6.1a, b, c) in order to prospect for the presence of separate buried combustion features in the vicinity of the mound. The survey was limited to one mound due to time constraints. The area of prospection partly coincided with the previously conducted survey of surface artefacts in this location (see Appendix Eight) and sought to test for the presence of hearths and potential camp sites potentially related to the operation of the mound.

The survey employed a Bartington Grad601-2 gradiometer (Figure 6.6) with survey lines collected at a 0.5 m spacing and 8 samples per meter using a zigzag collective direction and a range of 100nT. Five adjacent 20x20 m grids covered a total area of 20x100 m. The raw data was gridded using Snuffler software using the destripe and interpolate filters before being exported as an image file for interpretation.

Figure 6.5: A Grad 601 as used in the magnetic survey in the vicinity of mound HIS_2_23. Photograph retrieved 02/12/2022 from < www.bartington.com/products/gradiometers/grad601-single-axis/>.

6.3 Chapter summary

This chapter has outlined the methods evaluated and adopted for this study. Pilot studies on earth mound sediments from Weipa in northern Cape York were used to evaluate four methods, including SEM, FTIR, plant microfossil morphology and MS, for potential use on Calperum earth mound sediments (with the latter two adopted). Other methods adopted included aerial and field survey, excavation and onsite sieving of mound sediments for the retrieval of larger pieces of heat retainer, faunal material, artefacts, charcoal and photography for recording relevant images. LOI, sediment particle size, colour, pH and elemental profiling were selected to provide insights into mound formation and development and radiocarbon dating enabled a chronology to be established for the excavated mounds. Other methods which were used included spatial and elevation analysis using a real time kinetic device. The results from the range of methods which were eventually deployed are outlined in the next chapter.

Chapter Seven: Results

7.1 Introduction

This chapter presents the results obtained from the methods detailed in Chapter Six which were used to address the aims of this research as detailed in Chapter One. The results of analyses and chronology are largely presented separately but considered together when relevant. The data supporting this study is located at the Open Science Framework (Jones 2023).

7.2 Calperum results

7.2.1 Survey

The recording of earth mounds, via pedestrian survey at Calperum, has been ongoing since 2015 with a sample of 55 mounds recorded during this period (Jones 2016: Jones et al. 2017: Jones et al. 2022). See Figure 7.1 for a photomosaic of the six excavated mounds selected for this study.

7.2.2 Excavation

The physical attributes of the mounds selected for excavation are summarised in Table 7.1 with locations shown in Figures 6.1a, b, c and 7.11. Appendix Three provides details of all mounds recorded at Calperum. The stratigraphic diagrams for the six excavated mounds at Calperum are shown in Figure 7.7. Appendix Ten provides aerial photographs of mounds HCN21, HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3. An aerial photograph of HCN20 was not obtained due to equipment issues. While the mounds appear upon initial examination to be undifferentiated masses of mixed sediment, subtle variations in colour, texture, sediment characteristics and potentially moisture content, ultimately enabled some stratigraphic differences to be discerned in all mounds. The sediments contained a varying mixture of ashy sediment, degraded clay heat retainers, charcoal and mussel shell fragments with the occasional presence of other faunal and stone artefact material.

7.2.3 Contents analysis

The data for principal mound components are presented in Tables 7.2A to 7.2F. Heat retainer material, mussel shell and other faunal elements, charcoal, stone tool material,

Figure 7.1: The six excavated earth mound contexts and morphologies at Calperum. Left to right from the top of the image—HIS_2_21, HIS_2_22, HIS_2_23, RRWWS3, HCN20 and HCN21.

Table 7.1: Physical characteristics of mounds selected for excavation (Jones et al. 2022).

Code	Levee	Landform	Length (m)	Width (m)	Estimated Height (cm)	Shape	Area (sqm)	Highest point AHD (m)	Comments
RRWWS3	Y	Terrace flat	45	30	30	Ellipse	1060	18.2	Surface disrupted heat retainer visible
HIS_2_21	Y	Terrace flat	30	30	50	Circle	706	19.5	Prominent location, ashy, shell, rabbit damage
HIS_2_22	Y	Terrace flat	50	50	60	Circle	1963	19.4	Large area, prominent location, ashy, shell
HIS_2_23	Y	Terrace flat	30	30	50	Circle	706	19.4	Prominent location, ashy, shell
HCN20	Y	Terrace flat	20	14	20	Ellipse	220	21.0	Eroded mound
HCN21	Y	Terrace flat	40	23	20	Ellipse	772	20.0	Eroded mound

bioturbated sediment were quantified and percentages calculated for each excavated mound. The heat retainer component displayed considerable variability in nodule size and colour. The latter can range from black through red, light orange, brown to light beige, interpreted as resulting from varying exposures to heat during repeated cycles of cooking (Figures 7.8 and 7.9) (Klaver 1988; Martin 2006; Pardoe and Martin 2011:54; Westell and Wood 2014). The variation in heat retainer nodule size observed within the mounds probably relates, in part, to their breakdown through burning, digging and raking of mound contents. The deflated mound HCN20 provided an example of the possible range of heat retainer nodule sizes during its excavation revealing a number of large heat retainer nodules at the surface level of the excavation (Figure 7.8). The lower floodplain mounds (RRWWS3, HIS_2_21, HIS_2_22, HIS_2_23) show the dominance of heat retainer material in all excavated levels. In contrast the higher floodplain mounds (HCN20 and HCN21) provided evidence (Table 7.2A and 7.2B) of bioturbation by ants demonstrated by dry nodules of clay showing evidence of tunnelling (Figure 7.2) (Stephen Hasiotis pers. comm. 2021). HCN20 has a significant decline in heat retainer percentage below level 4. HCN21 demonstrated a dominance of ant bioturbation evidence and almost complete absence of heat retainer in levels 6 to 8 with a small percentage of the latter (1.8%) in level 9, which was the base level of the excavation. Mound HIS_2_21 had an isolated presence of ant bioturbation at level 5 (Table 7.2 C) while all other mounds did not display any disturbance of this type. Charcoal was spread through all of the excavations in small quantities with the occasional higher deposit associated with the localised preservation of charred plant material.

Figure 7.2: Examples of nodules resulting from bioturbation by ants from mound HCN21 level 5.

7.2.4 Faunal material

Faunal material present in the excavations included aquatic snail shell, crustacean gastroliths and fragments of small mammal and fish bones (Appendix Five). Freshwater mussel shell was present in all mounds, represented either as a lens of large (1–4 cm) fragments (as was observed in HCN20 and HCN21) and/or disseminated fragments of varying size which were present in all mounds (HCN20, HCN21, HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3). Tables 7.2A and 7.2B indicate relatively higher percentages of shell at levels 3 and 4 of both HCN20 and HCN21. This is also represented by shell lenses in the stratigraphic diagrams in Figures 7.7A and 7.7B. Six single intact valves were identified as *V. ambiguus,* five of which were very small (< 14 mm by 10 mm, 0.17 g) and the other larger (55 mm by 39 mm, 4.6 gm), in all other cases the shell was too fragmented for species level identification. Terrestrial mollusc taxa found in the sediments included one specimen each of *Cupedora* and *Cernuella*, genera of the terrestrial Camaenidae and Geomitridae families respectively (the latter specimen, found in level 1 of mound HIS_2_23, is a post European introduced species). Thirty eight specimens of freshwater taxa from the Planorbidae family were recorded, including the genera *Isidorella* (n = 35) and *Gryaulas* (n = 3) and 2 specimens of the genus *Plotiopsis* of the Thiaridae family. Planorbidae and Thiaridae members are found in association with aquatic plants in ponds, billabongs, swamps and slow moving streams (Ponder et al. 2020; Smith 1992; Smith and Kershaw 1979; Walker 1988). A small number of gastroliths and claw fragments from the common yabby (*Cherax destructor*) were also present .

The total weight of bone fragments recorded was 14.5 g, consisting of 19 individual fragments for which identification was attempted (Figure 7.3, Appendix 5). The result of an analysis of this material is summarised in Table 7.3. Bone fragments found in mound HIS_2_21 were confined to the upper three levels and were assigned to the species *Oryctolagus cuniculus* (European rabbit) which reflects the high level of bioturbation of this mound. Mound HIS-2_22 had a single vertebrae of an indeterminate genus of *Macropodidae* found in level 1 of the excavation. Mound HIS_2_23 had a range of bone fragments distributed through the excavation. These included two fragments of *Oryctolagus cuniculus* bone at levels 1 and 5, six fish vertebrae from levels 2, 3, 6 and 7, a partial left dentary of *Pseudomys bolami* (Bollam's mouse) from level 2, a pelvis and a parietal bone fragment of indeterminate mammalia genera from levels three and seven respectively and a vertebrae from a species of *Morelia* (non-venomous snake) from level 4. Level 1 of mounds RRWWS3 and HCN21 had a vertebrae from an indeterminate species of the genus *Elapidae* (venomous snake) and an indeterminate fish genus, respectively.

Table 7.2A: Mound HCN20 contents by category. Component percentages of interest, as noted in the text, are highlighted in red.

HCN20 Level	Sieve	Total weight (gm)	Ant Bioturb. Material (gm)	Heat retainer (gm)	Shell (gm)	Charcoal (gm)	Bone (gm)	Stone (gm)	HR %	Bioturb. %	Shell %	Charcoal %	Bone %
1	3 mm	1567.23	0	1488	55.88	23.35	0	0.6	94.9	0.0	3.6	1.5	0
	7 mm	2029.18	0	1807	6.18	216	0	0	89.1	0.0	0.3	10.6	0
2	3 mm	1685.6	0	1506	146.2	33.4	0	0	89.3	0.0	8.7	2.0	0
	7 mm	5282.7	0	5123	29.7	130	0	0	97.0	0.0	0.6	2.5	0
3	3 mm	130.4	0	75	39.6	15.8	0	0	57.5	0.0	30.4	12.1	0
	7 mm	1349.85	0	1230	87.65	32.2	0	0	91.1	0.0	6.5	2.4	0
4	3 mm	147.4	0	109.8	31.8	5.8	0	0	74.5	0.0	21.6	3.9	0
	7 mm	831.61	210.8	380	239	1.81	0	0	45.7	25.3	28.7	0.2	0
5	3 mm	598.9	310.7	255.4	28.9	3.9	0	0	42.6	51.9	4.8	0.7	0
	7 mm	770.08	474.4	151.7	131.58	12.4	0	0	19.7	61.6	17.1	1.6	0
6	3 mm	424.6	406	8.9	8	1.7	0	0	2.1	95.6	1.9	0.4	0
	7 mm	954.56	917.54	12.66	18.48	5.88	0	0	1.3	96.1	1.9	0.6	0

Table 7.2B: Mound HCN21 contents by category. Mussel shell percentages are highlighted in red.

HCN21 Level	Sieve	Total weight (gm)	Ant Bioturb. Material (gm)	Heat retainer (gm)	Shell (gm)	Charcoal (gm)	Bone (gm)	Stone (gm)	Heat retainer %	Bioturb. %	Shell %	Charcoal %	Bone %
1	3 mm	424.3	0	397.8	23.2	2.4	0.9	0	93.75	0.00	5.5	0.6	0.21
	7 mm	6003.8	0	5993.5	8.8	1.5	0	0	99.83	0.00	0.1	0.0	0
2	3 mm	1540.3	0	1499.2	35	6	0	0	97.34	0.00	2.3	0.4	0
	7 mm	1340.4	0	1250.2	**74.7**	3.2	0	0	94.13	0.00	5.6	0.2	0
3	3 mm	206.5	0	197.2	8	1.3	0	0	95.50	0.00	3.9	0.6	0
	7 mm	645.6	0	580.5	**37.6**	11.6	0	0	92.19	0.00	6.0	1.8	0
4	3 mm	367.6	0	355.9	9.5	1.3	0	0	97.05	0.00	2.6	0.4	0
	7 mm	441.7	42.8	396.2	2.69	0	0	0	89.70	9.69	0.6	0.0	0
5	3 mm	437.0	68.7	354	9.1	5.2	0	0	81.01	15.72	2.1	1.2	0
	7 mm	386.9	52.5	323.4	5.5	0.4	0	0	84.70	13.75	1.4	0.1	0
6	3 mm	326.9	317.6	0	2.2	6	0	0	0.00	97.48	0.7	1.8	0
	7 mm	509.7	503	0	0	3.6	0	0	0.00	99.29	0.0	0.7	0
7	3 mm	321.2	315.3	0	2.8	2.8	0	0	0.00	98.25	0.9	0.9	0
	7 mm	500.2	493.1	0	0	5	0	0	0.00	99.00	0.0	1.0	0
8	3 mm	410.3	405.1	0	0.1	4.51	0	0	0.00	98.87	0.0	1.1	0
	7 mm	305.6	301.3	0.51	0	3.8	0	0	0.17	98.59	0.0	1.2	0
9	3 mm	277.2	277.1	0	0	0.1	0	0	0.00	99.96	0.0	0.0	0
	7 mm	1353.1	1326	24	0.05	3.04	0	0	1.8	98.0	0.0	0.2	0

Table 7.2C: Mound HIS_2_21 contents by category.

HIS_2_21 Level	Sieve	Total weight (gm)	Ant Bioturb. Material (gm)	Heat retainer (gm)	Shell (gm)	Charcoal (gm)	Bone (gm)	Stone (gm)	Heat retainer %	Bioturb. %	Shell %	Charcoal %	Bone %
1	1 mm	189.3	0	173	10.6	4	1.7	0	91.4	0.00	5.6	2.1	0.9
	3 mm	317.1	0	315.5	1.6	0	0	0	99.5	0.00	0.5	0.0	0.0
2	1 mm	183.7	0	179	2.6	0	2.1	0	97.4	0.00	1.4	0.0	1.1
	3 mm	1159.4	0	1145	4.7	1.9	7.8	0	98.8	0.00	0.4	0.2	0.7
3	1 mm	240.47	0	234	4.57	1.9	0	0	97.3	0.00	1.9	0.8	0.0
	3 mm	1158.75	0	1150	4.35	0	4.4	0	99.2	0.00	0.4	0.0	0.4
4	1 mm	396.6	0	396	0.6	0	0	0	99.8	0.00	0.2	0.0	0.0
	3 mm	2112.47	0	2072	12.3	21.7	6.47	0	98.1	0.00	0.6	1.0	0.3
5	1 mm	411.32	0	409	2.32	0	0	0	99.4	0.00	0.6	0.0	0.0
	3 mm	1285.08	21.7	1250	13.38	0	0	0	97.3	1.69	1.0	0.0	0.0
6	1 mm	676.97	0	676	0.97	0	0	0	99.9	0.00	0.1	0.0	0.0
	3 mm	1438.7	0	1436	2.7	0	0	0	99.8	0.00	0.2	0.0	0.0

Table 7.2D: Mound HIS_2_22 contents by category

HIS_2_22 Level	Sieve	Total weight (gm)	Ant Bioturb. Material (gm)	Heat retainer (gm)	Shell (gm)	Charcoal (gm)	Bone (gm)	Stone (gm)	Heat retainer %	Bioturb. %	Shell %	Charcoal %	Bone %
1	1 mm	377.3	0	369	4.2	1.67	2.41	0	97.8	0	1.11	0.44	0.64
	3 mm	2187.4	0	2181	0.92	5.2	0	0.25	99.7	0	0.24	0.24	0.00
2	1 mm	108.71	0	96.98	0.11	11.62	0	0	89.2	0	0.03	10.69	0.00
	3 mm	1234.5	0	1222	0.63	11.9	0	0	99.0	0	0.17	0.96	0.00
3	1 mm	102.64	0	94.6	0.65	7.4	0	0	92.2	0	0.17	7.21	0.00
	3 mm	1428.8	0	1390	0.63	38.14	0	0	97.3	0	0.17	2.67	0.00
4	1 mm	122.31	0	100.7	12.05	9.56	0	0	82.3	0	3.19	7.82	0.00
	3 mm	1904.6	0	1876	0.39	28.25	0	0	98.5	0	0.10	1.48	0.00
5	1 mm	109.7	0	106.65	0.66	2.39	0	0	97.2	0	0.17	2.18	0.00
	3 mm	1513.5	0	1503	0.99	9.51	0	0	99.3	0	0.26	0.63	0.00
6	1 mm	107.76	0	107.18	0.2	0.38	0	0	99.5	0	0.05	0.35	0.00
	3 mm	1424.3	0	1414	3.04	7.28	0	0	99.3	0	0.81	0.51	0.00
7	1 mm	103.98	0	100.23	2.57	1.18	0	0	96.4	0	0.68	1.13	0.00
	3 mm	1839.76	0	1833	0.59	6.17	0	0	99.6	0	0.16	0.34	0.00
8	1 mm	332.94	0	331.75	0.54	0.65	0	0	99.6	0	0.14	0.20	0.00
	3 mm	2523.41	0	2518	0.52	4.89	0	0	99.8	0	0.14	0.19	0.00
9	1 mm	849.45	0	849	0.03	0.42	0	0	99.9	0	0.01	0.05	0.00
	3 mm	2571.57	0	2571	0	0.57	0	0	100.0	0	0.00	0.02	0.00

Table 7.2E: Mound HIS_2_23 contents by category.

HIS_2_23 level	Sieve	Total weight (gm)	Bioturb. Material (gm)	Heat retainer (gm)	Shell (gm)	Charcoal (gm)	Bone (gm)	Stone (gm)	Heat retainer %	Bioturb. Material %	Shell %	Charcoal %	Bone %
1	1 mm	392.7	0	381.1	10.5	0.28	0.85	0	97.0	0	2.7	0.1	0.2
	3 mm	2170	0	2155	11.7	1.13	1.15	1.42	99.3	0	0.5	0.1	0.1
2	1 mm	341.3	0	336	1.5	2.6	1.2	0	98.4	0	0.4	0.8	0.4
	3 mm	2512	0	2500	8.6	2.5	0.5	0	99.5	0	0.3	0.1	0.0
3	1 mm	418	0	412	4.2	1.6	0	0	98.6	0	1.0	0.4	0.0
	3 mm	1746	0	1705	34.7	4.4	1.47	0.75	97.7	0	2.0	0.3	0.1
4	1 mm	541	0	530	14.5	4.9	0.54	0	96.5	0	2.6	0.9	0.1
	3 mm	2673	0	2639	35.0	15.79	0.6	0	98.7	0	1.3	0.6	0.0
5	1 mm	175	0	170	4.8	0	0	0	96.9	0	2.7	0.0	0.0
	3 mm	1170	0	1150	8.65	11.8	0	0	98.3	0	0.7	1.0	0.0
6	1 mm	173	0	173	0.2	0	0	0	99.9	0	0.1	0.0	0.0
	3 mm	1884	0	1880	2.5	0.2	1.6	0	99.8	0	0.1	0.0	0.1
7	1 mm	239	0	232	0.57	6.3	0.3	0	97.0	0	0.2	2.6	0.1
	3 mm	768	0	707	1.12	60	0	0	92.0	0	0.1	7.8	0.0

Table 7.2F: RRWWS3 contents by category.

RRWWS3 Level	Sieve	Total weight (gm)	Bioturb. Material (gm)	Heat retainer (gm)	Shell (gm)	Charcoal (gm)	Bone (gm)	Stone (gm)	Heat retainer %	Bioturb. %	Shell %	Charcoal %	Bone %
1	1 mm	415	0	401.35	4.54	7.75	0.9	0	96.8	0	1.10	1.87	0.45
	3 mm	4502	0	4498.4	1.67	0.74	1.1	0	99.9	0	0.04	0.02	0.02
2	1 mm	732	0	732	0.2	0	0	0	100.0	0	0.03	0.00	0.00
	3 mm	1849	0	1849	0	0	0	0	100.0	0	0.00	0.00	0.00
3	1 mm	510	0	509	0.2	0.3	0	0	99.9	0	0.04	0.06	0.01
	3 mm	1424	0	1424	0	0	0	0	100.0	0	0.00	0.00	0.00
4	1 mm	376	0	372	2.22	1.79	0	0	98.9	0	0.59	0.48	0.00
	3 mm	2769	0	2763	2.42	3.67	0	0	99.8	0	0.09	0.13	0.00
5	1 mm	905	0	903	1	1	0	0	99.8	0	0.11	0.11	0.00
	3 mm	3214	0	3210	1.01	3.1	0	0	99.9	0	0.03	0.10	0.00
6	1 mm	880	0	880	0	0.1	0	14.86	100.0	0	0.00	0.01	0.00
	3 mm	3220	0	3220	0	0.1	0	0	100.0	0	0.00	0.00	0.00
7	1 mm	244	0	241	1.3	1.22	0	0	99.0	0	0.53	0.50	0.00
	3 mm	2153	0	2140	0	13.4	0	0	99.4	0	0.00	0.62	0.00
8	1 mm	592	0	592	0	0	0	0	100.0	0	0.00	0.00	0.00
	3 mm	2692	0	0	0	0	0	0	0.0	0	0.00	0.00	0.00

Table 7.3: Detail of bone from all six excavated mounds.

Site	Level	Size mm	Description	Description	NISP	MNI	Notes	Common Name
HIS_2_21	1		I1	*Oryctolagus cuniculus*	1	1		
HIS_2_21	2	>3	left talus	*Oryctolagus cuniculus*	1	1		
HIS_2_21	2	>3.2	left femoral head, metacarpal	*Oryctolagus cuniculus*	2	1		
HIS_2_21	3	>3.2	metatarsal	*Oryctolagus cuniculus*	1	1		
HIS_2_22	1		vertebra	c.f. Macropodidae gen. et. sp. indet.	1	1		
HIS_2_23	1		left dentary, right talus	*Oryctolagus cuniculus*	2	1		
HIS_2_23	2	>1	small vertebra	Fish gen. et. sp. indet.	1	1		
HIS_2_23	2	>3.2	small vertebra	Fish gen. et. sp. indet.	1	1		
HIS_2_23	2	>1	left dentary, missing posterior portion, m1-3	*Pseudomys bolami*	1	1		Bollam's Mouse
HIS_2_23	3	>3.2	vertebra and spine	Fish gen. et. sp. indet.	2	1		
HIS_2_23	3	>3.2	pelvis fragment	Mammalia gen. et. sp. indet.	1	1	Small mammal	
HIS_2_23	4	>3.2	vertebra	*Morelia* sp. indet.	1	1	Snake	
HIS_2_23	5	>1	distal phalanx	c.f. *Oryctolagus cuniculus*	1	1		
HIS_2_23	6	>3.2	vertebra (fragment)	Fish gen. et. sp. indet.	1	1		
HIS_2_23	7	>3.2	parietal	Mammalia gen. et. sp. indet.	1	1		
HIS_2_23	7	>3.2	small vertebra	Fish gen. et. sp. indet.	1	1		
HIS_2_23	7	>3.2	vertebra	Fish gen. et. sp. indet.	1	1		
RRWWS3	1	>3.2	vertebra	Elapidae gen. et. sp. indet.	1	1		
HCN21	1	>3	vertebra	Fish gen. et. sp. indet.	1	1		

Figure 7.3: Samples of faunal material found within excavated mounds. From top left—dentary from *P. bolami* (HIS_2_3 L2), top right—aquatic snail shell *Isidorella newcombi* (HIS_2_22 L5), bottom left femoral head and metacarpal *O. cuninculus* (HIS_2_21 L2) and bottom right—gastrolith from *C. destructor* (HIS-2_21 L1).

7.2.5 Artefacts

A detailed stone artefact survey and analysis was beyond the scope of this study, however, details and images of artefacts found in the excavated mounds were recorded (see Appendix Six for all data and Figure 7.4 for sample images). The material comprised small numbers of fragments of chert and silcrete, and several irregular pieces of silcrete (n = 10, total weight 26.7 g). In addition to the above, surface surveys of stone artefacts were conducted in the immediate vicinity of the lower floodplain mound group comprising HIS_2_21, HIS_2_ 22 and HIS_2_23 (see Figures 6.1a, 8.4 and Appendix Eight for a selection of photographs and descriptions). The surface survey was restricted due to limited field time

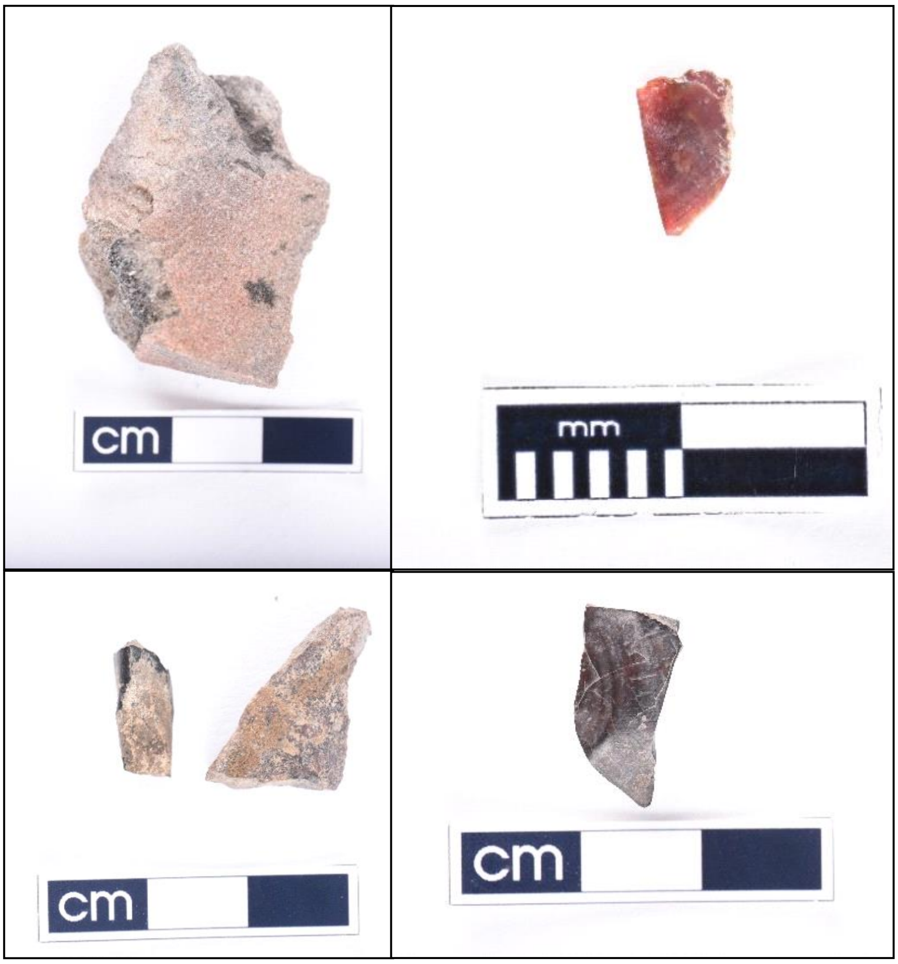


Figure 7.4: Examples of stone tool material found within excavated mounds. Left to right from top, fragment of silcrete RRWWS3 L6, fragment of red chert HIS_2_23 L3, fragments of silcrete HIS_2_23 L1 and flaked piece of dark chert HIS_2_22 L5 (see also Appendix Six).

but provided a background assessment of artefact discard associated with a grouping of mounds. The material used for tools which were discarded in the vicinity of the three mounds HIS_2_21, HIS_2_ 22 and HIS_2_23) were heavily curated and included chert (n = 47), quartzite/silcrete (n = 24), sandstone (n = 11) and possibly glass (n = 12) (Appendix Eight). Average length, width and thickness of stone artefacts were 30 mm, 24 mm and 10 mm respectively which were consistent with previous studies of stone artefacts at Calperum (Incerti 2018; Munt 2022; Thredgold et al. 2017; see also Westell and Wood 2014:53).

7.2.6 Sediment analyses

The data from grain size, MS and LOI analyses are included in Appendix Four. The granulometry results are summarised in Figures 7.12, 7.13 and 7.14, indicating that all mounds have relatively homogenous grain size distributions, but some variations exist. For instance, mounds HCN20 and HCN21 show higher proportions of fine sediments below level

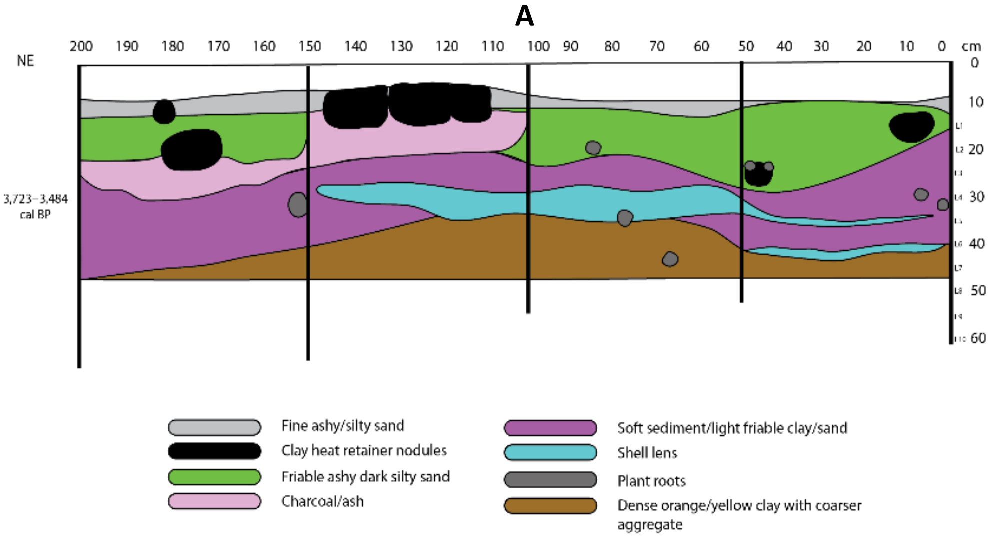
2, HIS_2_23 and HIS_2_21 show a regular grain size depth profile, and HIS_2_22 and RRWWS3 show a decrease in the proportion of finer sediments below level 2. RRWWS3 contained a sandy layer, noted during excavation, at the base of level 4 extending into level 5. Both RRWWS3 and HIS_2_22 indicate a dominance of medium sized sand grains and a reduction in organic content at about level 4/5, which was not observed in the older mound HIS_2_21 and the younger HIS_2_23 (Figures 7.12 and 7.14). This may reflect a discrete period of increased depositional energy related to a flood event. The granulometry results from the non-site control data floodplain auger sediment samples (Figure 7.13) show significant differences to those obtained from the mounds. Grain size analysis shows higher percentages of coarser grained material at all levels than the profiles obtained for the mound sediments.

The amount of organic material in all mounds range from 1–2.5%. Carbonate percentages range from 0.25–1.25% (Figure 7.14). Low frequency MS values of sediments were recorded between 0e+00 and 2e-06 SI units. The low frequency MS readings (Figure 7.14) show a gradual decrease with depth in all sites, except for mounds HIS_2_22, HCN20 and HCN21. HIS_2_22 shows an increase in low frequency MS, and LOI to level 4 then a subsequent gradual decrease. Mounds HCN20 and HCN21 exhibit a sharp reduction in all three parameters between levels 1 and 2 of each excavation except for carbonate in HCN20. LOI of organic material in mound RRWWS3 shows a decrease in organic content between levels 4 and 5, and HCN21, which showed a slight increase of organic material at level 9. A discrete lens of sand at levels 4–5 (Figures 7.5, 7.6 and 7.7C) was noted during the excavation of mound RRWWS3, which is potentially related to an increase in coarser grain fractions in the relatively low resolution grain size results (Figure 7.12) and is visible in the stratigraphic diagram Figure 7.7. HIS_2_22 also demonstrates an increase in coarser material at level 5. LOI of carbonate show some variation, albeit over a limited range, with depth. Mound HCN20 increased from levels 1 to 3 then decreased below that level, mound HIS_2_21 increased with depth, HIS_2_22 increased from levels 1 to 4 then reduced, HIS_2_23 increased from levels 1 to 3 then reduced. The non-site control data floodplain auger sediment samples (Figure 7.13) show little variation in low frequency MS and LOI with depth, in contrast to the mound samples. Low frequency MS readings at the surface of the

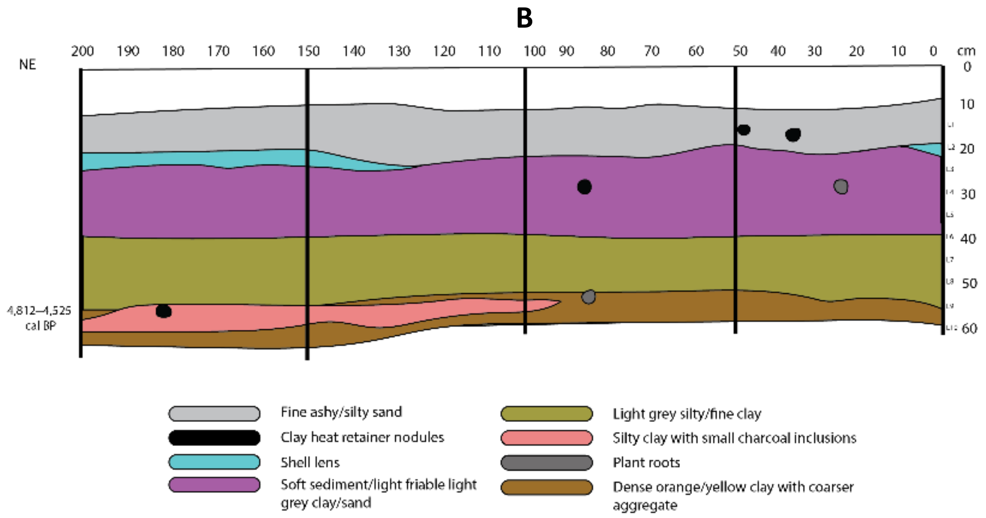
Figure 7.5: Horizontal view of sand lens uncovered at levels 4–5 in mound RRWWS3.

Figure 7.6: Vertical view of the RRWWS3 excavation showing a sand lens evident in levels 4–5 in the west and north sides of the mound.

Stratigraphic sections for earth mound HCN20

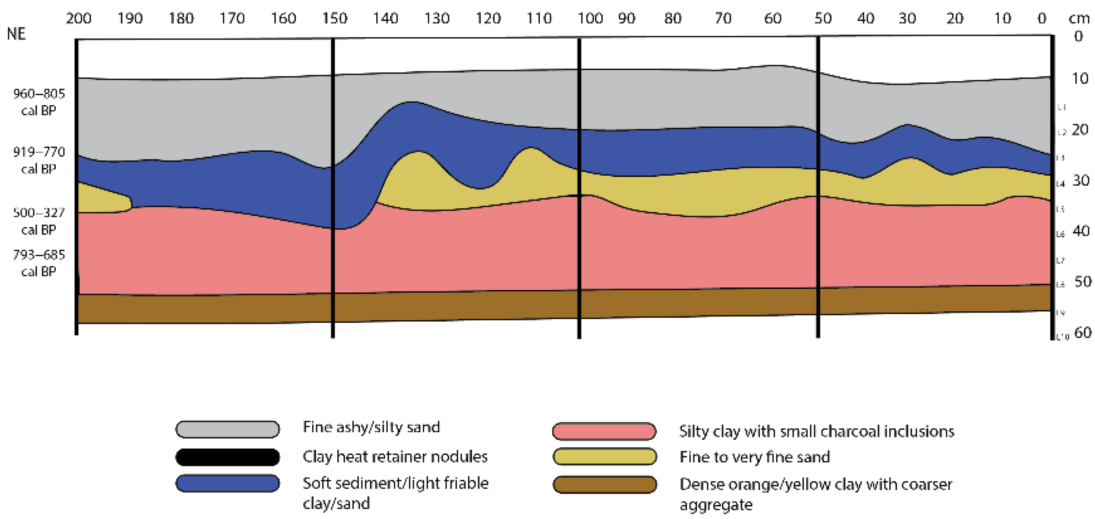


Stratigraphic sections for earth mound HCN21



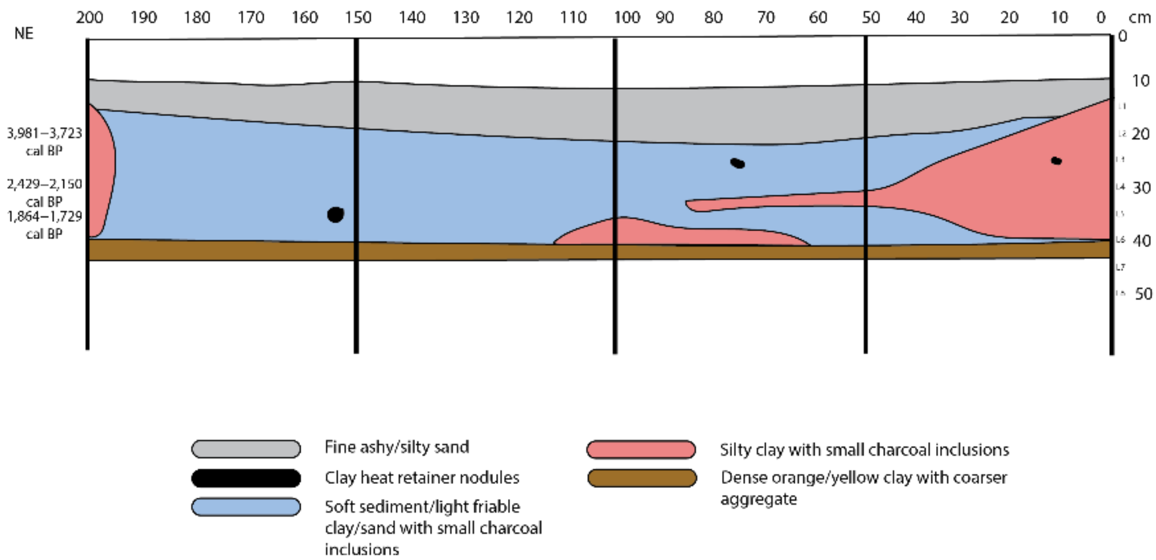
Stratigraphic sections for earth mound RRWWS3

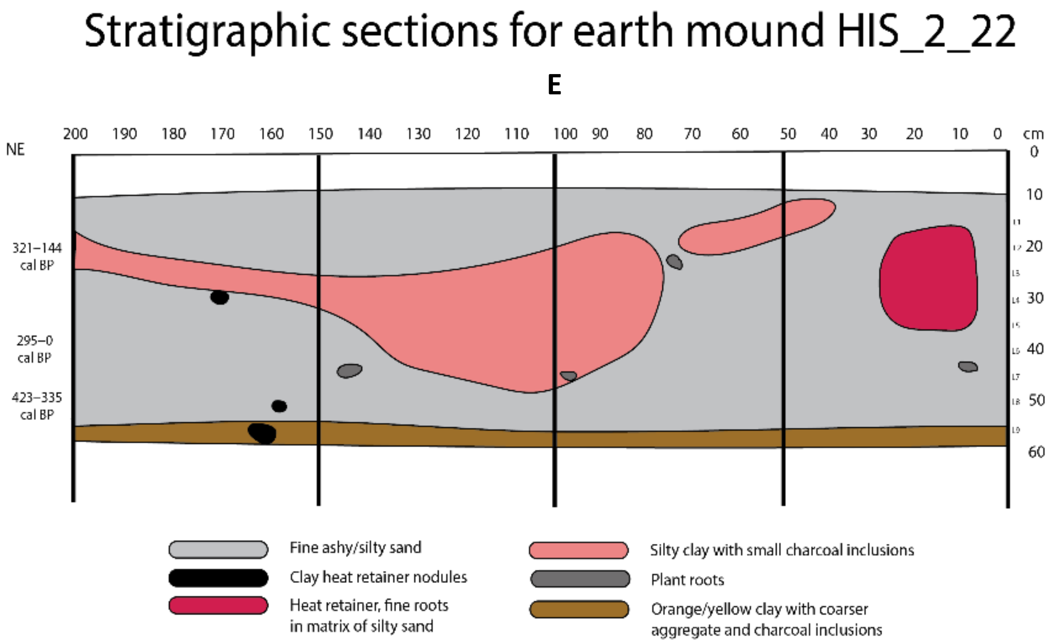
C



Stratigraphic sections for earth mound HIS_2_21

D





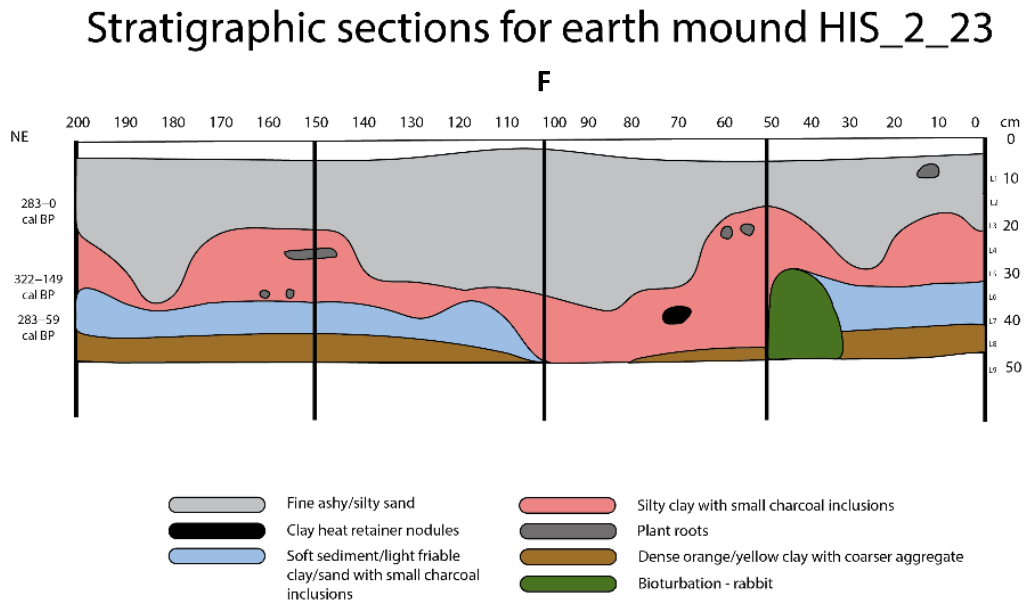


Figure 7.7: Stratigraphic diagrams are listed A–F for the six excavations showing identified sediment units. Elevation 0 marks the string line. Horizontal and vertical dimensions are in centimetres. Faces are from left to right E, S, W, N. The lower edge of each excavation unit (XU) is indicated by the letter L followed by the relevant XU number. Age determinations from the initial dating program (ANSTO references AP12553/12393) are shown at the relevant level to the left of each diagram.

Figure 7.8: View of HCN20 excavation showing large nodules of heat retainer at the surface. Photograph R. Jones, September 2020.

Figure 7.9: RMMAC member Jennifer Grace holding examples of clay heat retainers. Photograph A. Roberts, April 2016

Figure 7.10: The author recording volume MS values at the RRWWS3 excavation. Photograph C. Morton, October 2019.

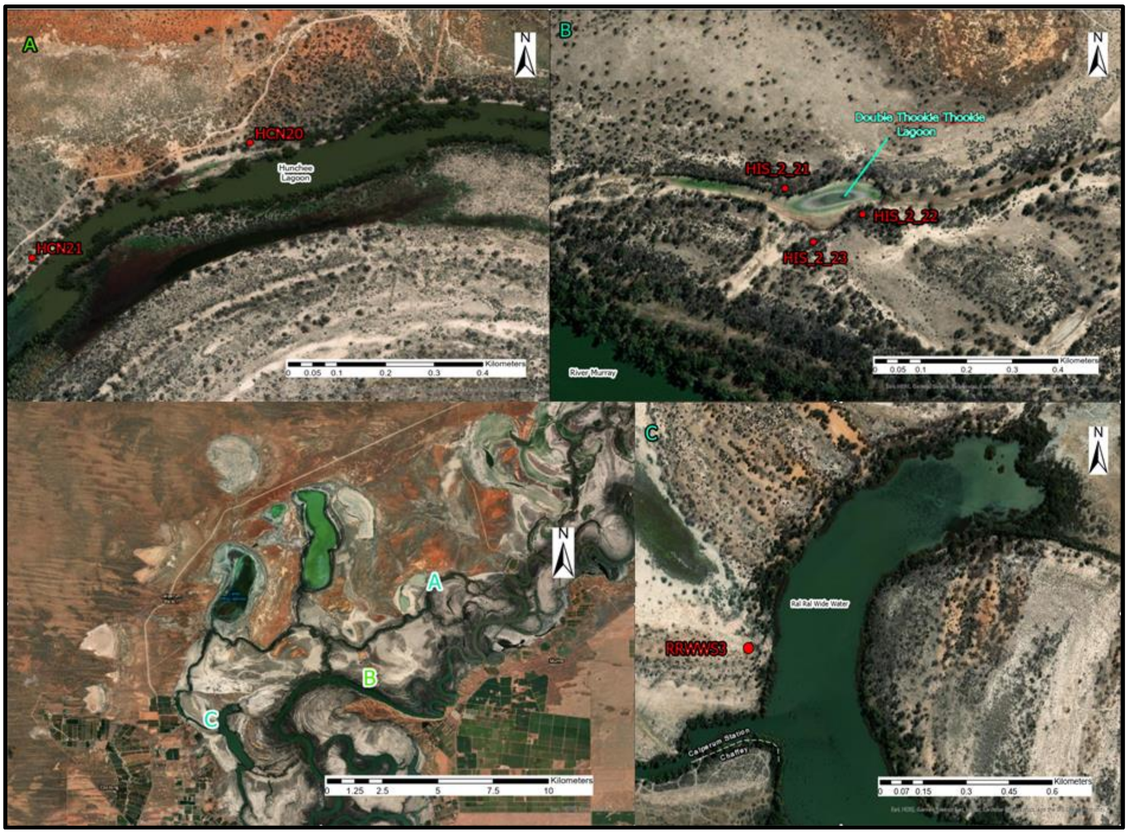


Figure 7.11: A, B and C denote the landscape locations for all excavated mounds (labelled). Note association with water features.

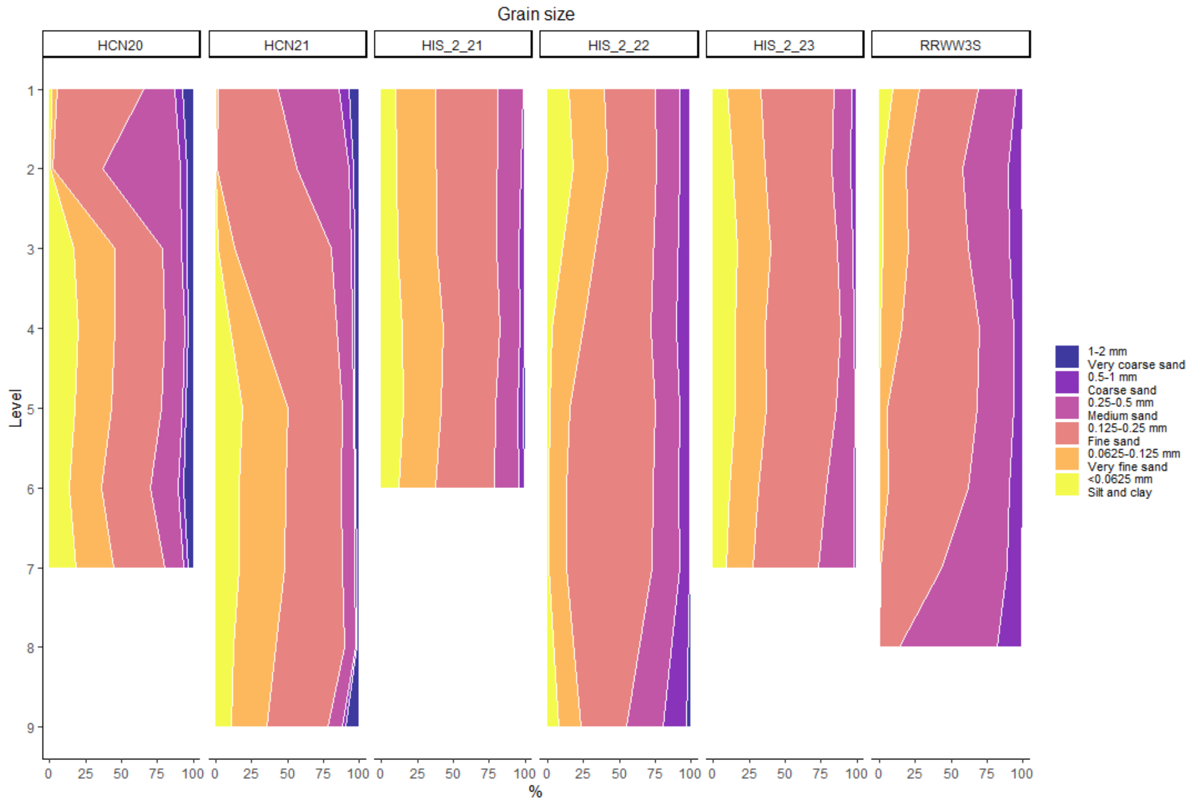


Figure 7.12: Sediment grain size profiles for all mounds, level numbers refer to 5 cm spits.

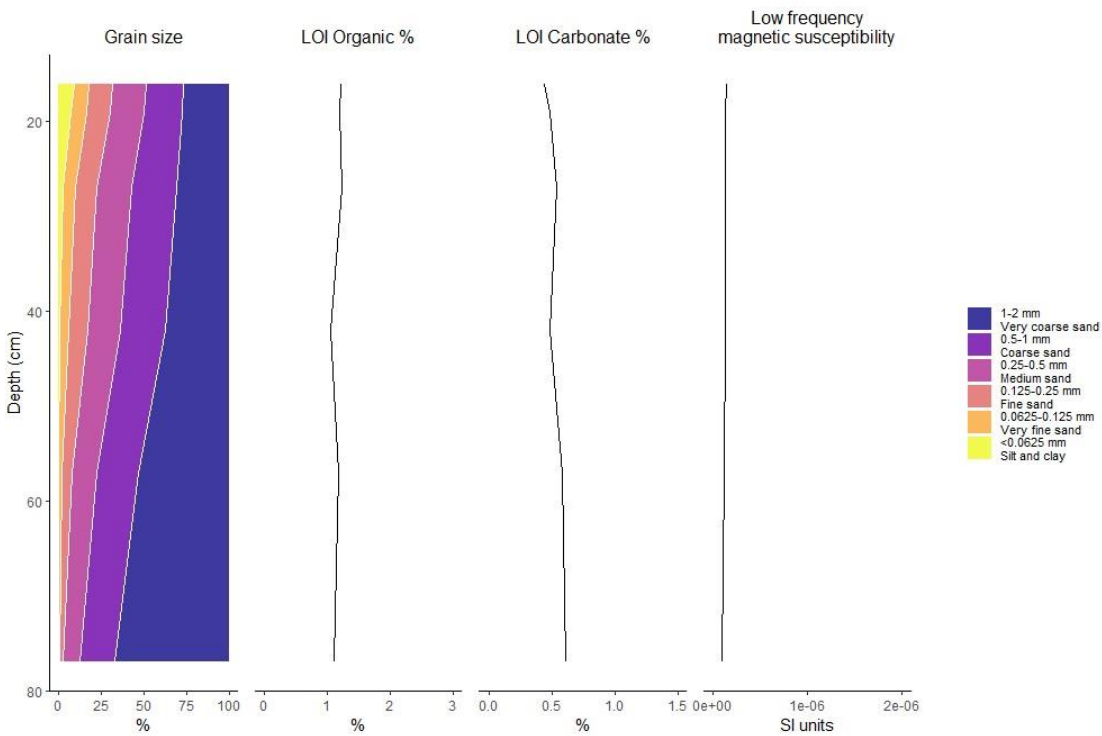


Figure 7.13: MS, LOI and grain size profiles for the Hunchee floodplain auger sediment samples.

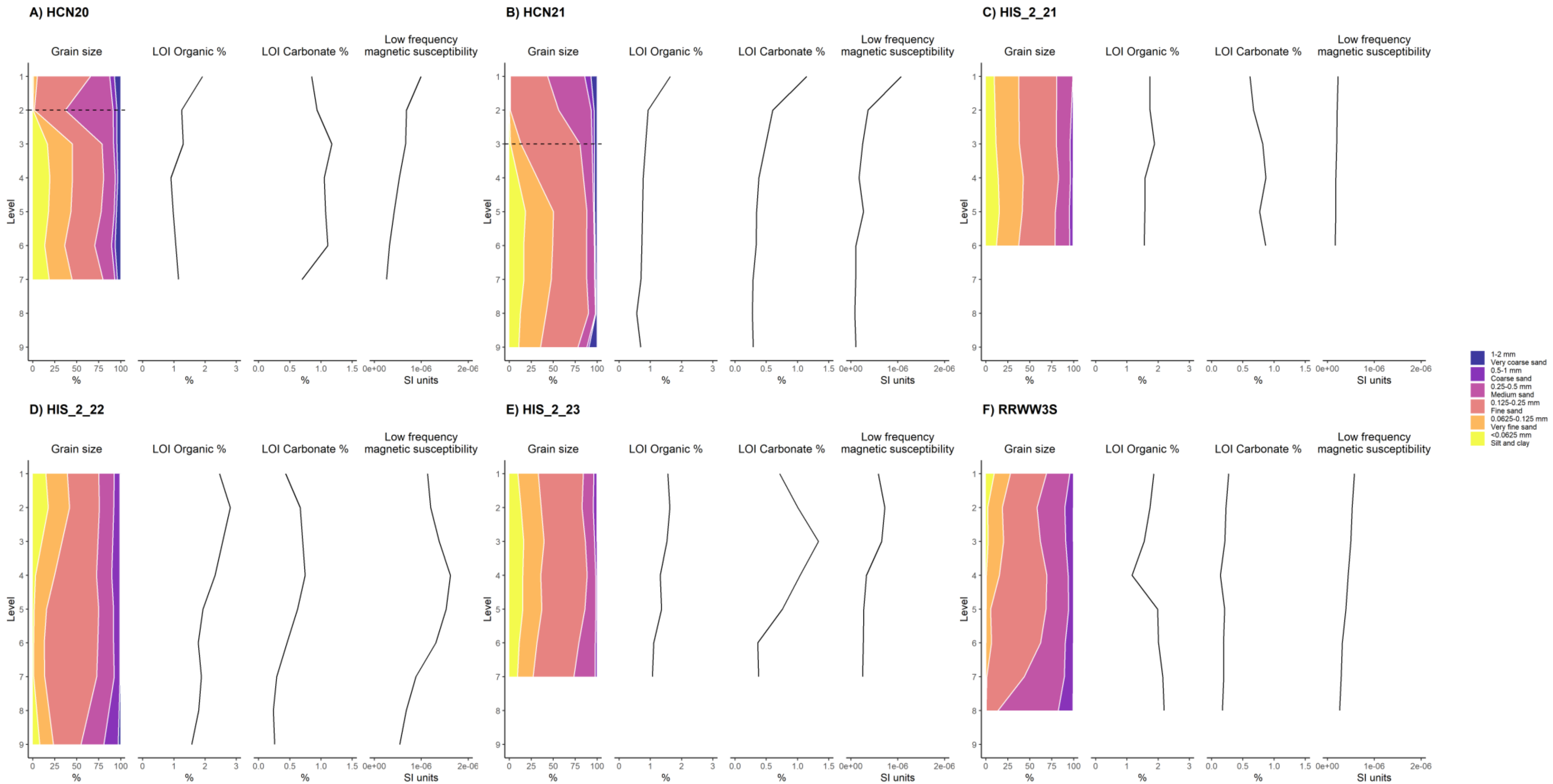


Figure 7.14: MS, LOI and sediment grain size for all mounds, level numbers refer to 5 cm spits. Note: see Figure 10 for a direct comparison of grain size profile by depth level of each mound.

mounds are between 8 to 10 times higher magnitude than the equivalent floodplain results. However, this difference reduces with depth. Figure 7.10 depicts vertical magnetic susceptibility readings (volume) being taken in the field for mound RRWWS3. Mass MS values taken from samples in the laboratory were used for reporting this work.

7.2.7 Radiocarbon dating at Calperum

The initial radiocarbon dating programs in 2019 and 2020 (ANSTO grant references AP12393/12553) at Calperum included 13 ages (11 from mussel shell and two from charcoal) from the four lower floodplain mounds HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3 (Table 7.4). Two ages (one from shell and one from charcoal) were obtained later from the higher floodplain mounds HCN20 (WK52024) and HCN21 (WK52025) and were tested at the University of Waikato Radiocarbon Dating Laboratory. Dates from this first round range from mound HIS_2_23 at 283–0 cal BP (OZZ572) (obtained from shell) through to level 9 of mound HCN21 at 4807–4442 cal BP (WK52025) (obtained from charcoal). The calibrated age estimations are listed by mound in Table 7.4. The age ranges of all 15 ages are plotted in chronological order in Figure 7.15. Figure 7.16 provides a plot of age ranges against depth for the four lower floodplain mounds HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3.

A further 13 radiocarbon dates were granted in early 2021 (AP12957) for a second dating program for mounds HCN20 and HCN21. This was initiated to investigate the provenance of charcoal and the mussel shell lenses found within these mounds. Calibrated dates from the second round of testing for mounds HCN20 and HCN21 range from 4803–4423 (OZAN64) to 280–28 cal BP (OZAN58), both of which were obtained from charcoal (Table 7.5).

Table 7.6 details two age determinations of 4960–4846 cal BP (WK53028) at 16 cm and 2292–2004 cal BP (WK53029) at 57 cm for the Hunchee auger samples. The age ranges indicate an inversion but was interpreted as confirming the sequence 0 to 57 cm from the surface as late Holocene and suitable as a source of data for comparison with mound deposits of similar age. Table 7.6 also includes an age of 960-805 cal BP (OZX285) for a shell sample from the surface of a

Table 7.4: Summary of the first rounds of calibrated age determinations (AP12553/12393) by mound. Mound RRWWS3 is co-labelled as CAPRI17_04 as the latter designation was used for radiocarbon dating.

ID	XU/ Level	Laboratory code	Depth from surface (cm)	Material	$^{\delta 13}C$ (‰)	CRA (years BP ± 1 σ error)	Calibrated Age (cal BP 95.4%)
HIS_2_21	2	OZZ566	5–9	Shell	-5.8+/-0.4	3610 +/- 30	3981–3723
HIS_2_21	4	OZZ567	15–19	Shell	-9.8 +/- 0.1	2360 +/- 30	2429–2150
HIS_2_21	6	OZZ568	25–29	Shell	-7.2 +/- 0.1	1915 +/- 30	1864–1729
HIS_2_22	2	OZZ569	5–9	Shell	-8.5 +/- 0.1	260 +/- 30	321–144
HIS_2_22	5	OZZ570	20–24	Shell	-6.5 +/- 0.2	210 +/- 30	295–0
HIS_2_22	8	OZZ571	35–39	Shell	-12.1 +/- 0.2	465 +/- 30	523–335
HIS_2_23	2	OZZ572	5–9	Shell	-8.2 +/- 0.1	190 +/- 25	283–0
HIS_2_23	5	OZZ573	20–24	Shell	-8.3 +/- 0.3	270 +/- 25	322–149
HIS_2_23	7a	OZAB05	30–34	Shell	-11.7+/-0.1	190+/-25	283–59
CAPRI17_04_01 (RRWWS3)	1	OZZ991	0–4	Shell	-5.9+/-0.1	1045+/-25	960–805
CAPRI17_04_02 (RRWWS3)	3	OZZ992	10–14	Shell	-8.4+/-0.2	970+/-25	919–770
CAPRI17_04_03 (RRWWS3)	5	OZZ993	20–24	Char.	-25.8+/-0.1	420+/-25	500–327
CAPRI17_04_04 (RRWWS3)	7	OZZ994	30–34	Char.	-21.1+/-0.2	885+/-20	793–685

Table 7.5: Summary of the second round (AP12957) of calibrated age determinations by mound. Samples HCN20_04 and HCN21_09 were analysed separately at the Waikato Radiocarbon Dating Laboratory.

ID	XU/ Level	Laboratory code	Depth from surface (cm)	Material	$^{\delta 13}C$ (‰)	CRA (years BP ± 1 σ error)	Calibrated Age (cal BP 95.4%)
HCN20_2_S	2	OZAN52	5–9	Shell	-9.2 +/- 0.1	200+/-50	296–32
HCN20_2_C	2	OZAN53	5–9	Char.	-29.2 +/- 0.1	355+/-25	461–306
HCN20_4_S	4	OZAN54	15–19	Shell	-8.6 +/- 0.2	3325+/-35	3618–3396
HCN20_4_C	4	OZAN55	15–19	Char.	-24.1 +/- 0.1	Modern	Modern
HCN20_04	4	WK52024	15–19	Shell	-8.5+/-0.3	3386+/-45	3700–3452
HCN20_6_S	6	OZAN56	25–29	Shell	-9.1 +/- 0.2	3165+/-30	3442–3231
HCN20_6_C	6	OZAN57	25–29	Char.	-25.7 +/- 0.1	420+/-30	502–326
HCN20_7_C	7	OZAN58	30–34	Char.	-26.8 +/- 0.2	180+/-25	280–0
HCN21_1_S	1	OZAN59	0–4	Shell	-7.3 +/- 0.2	975+/-30	922–770
HCN21_3_S	3	OZAN60	10–14	Shell	-8.6 +/- 0.3	2475+/-30	2703–2354
HCN21_3_C	3	OZAN61	10–14	Char.	-21.9 +/- 0.1	775+/-30	727–570
HCN21_6_S	6	OZAN62	25–29	Shell	-9.3 +/- 0.1	3860+/-30	4404–4092
HCN21_6_C	6	OZAN63	25–29	Char.	-24.9 +/- 0.1	3925+/-30	4418–4158
HCN21_9_C	9	OZAN64	40–44	Char.	-23.5 +/- 0.1	4105+/-30	4803–4423
HCN21_09	9	WK52025	40–44	Char.	NA	4118+/-21	4807–4442

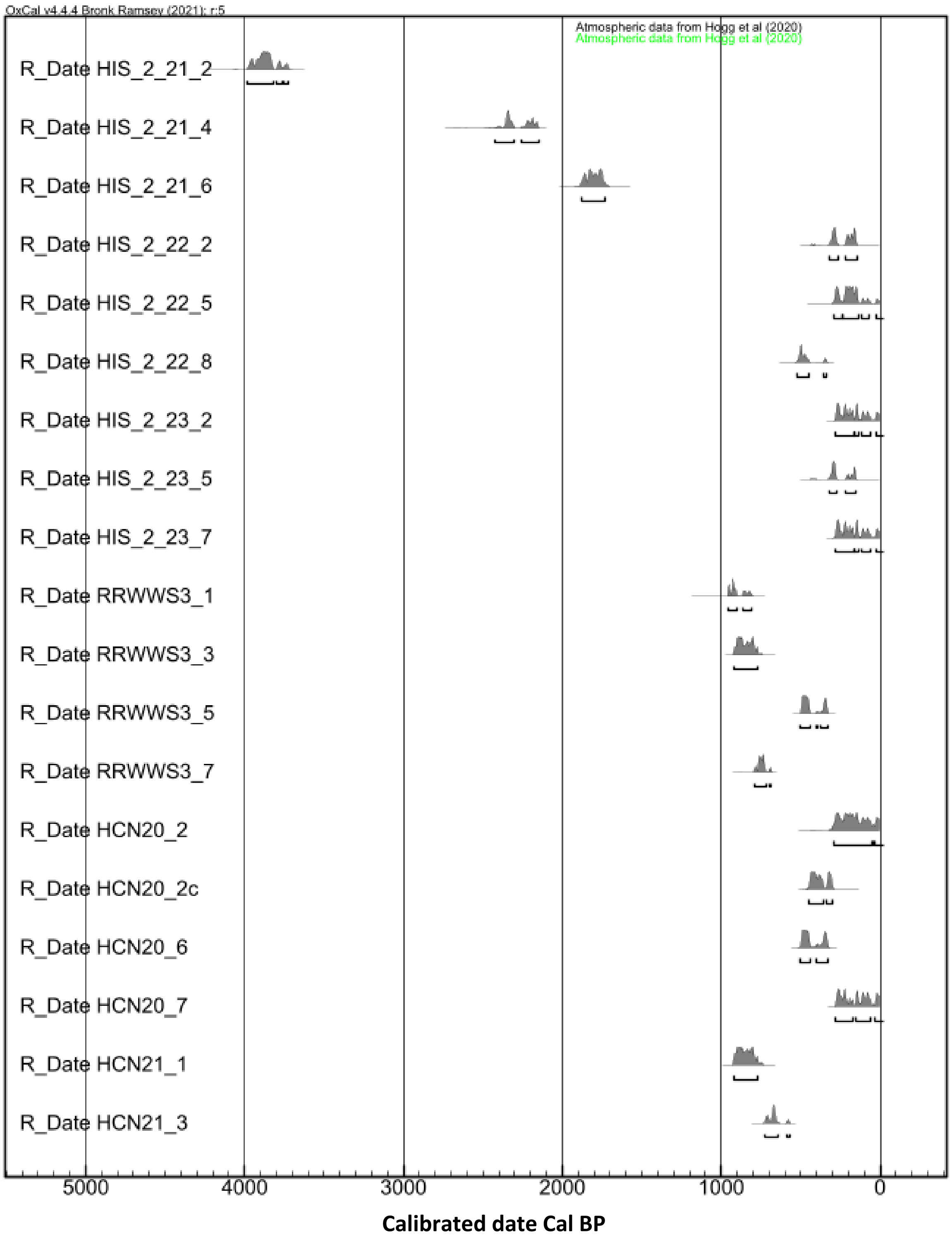


Figure 7.15: Calibrated radiocarbon dates for the six excavated mounds HIS_2_21, HIS_2_22, HIS_2_23, RRWWS3, HCN20 and HCN21. Dates associated with the formation of mounds HCN20 and HCN21 are shown. Dates from the shell lenses located below HCN20 and HCN 21 are not included.

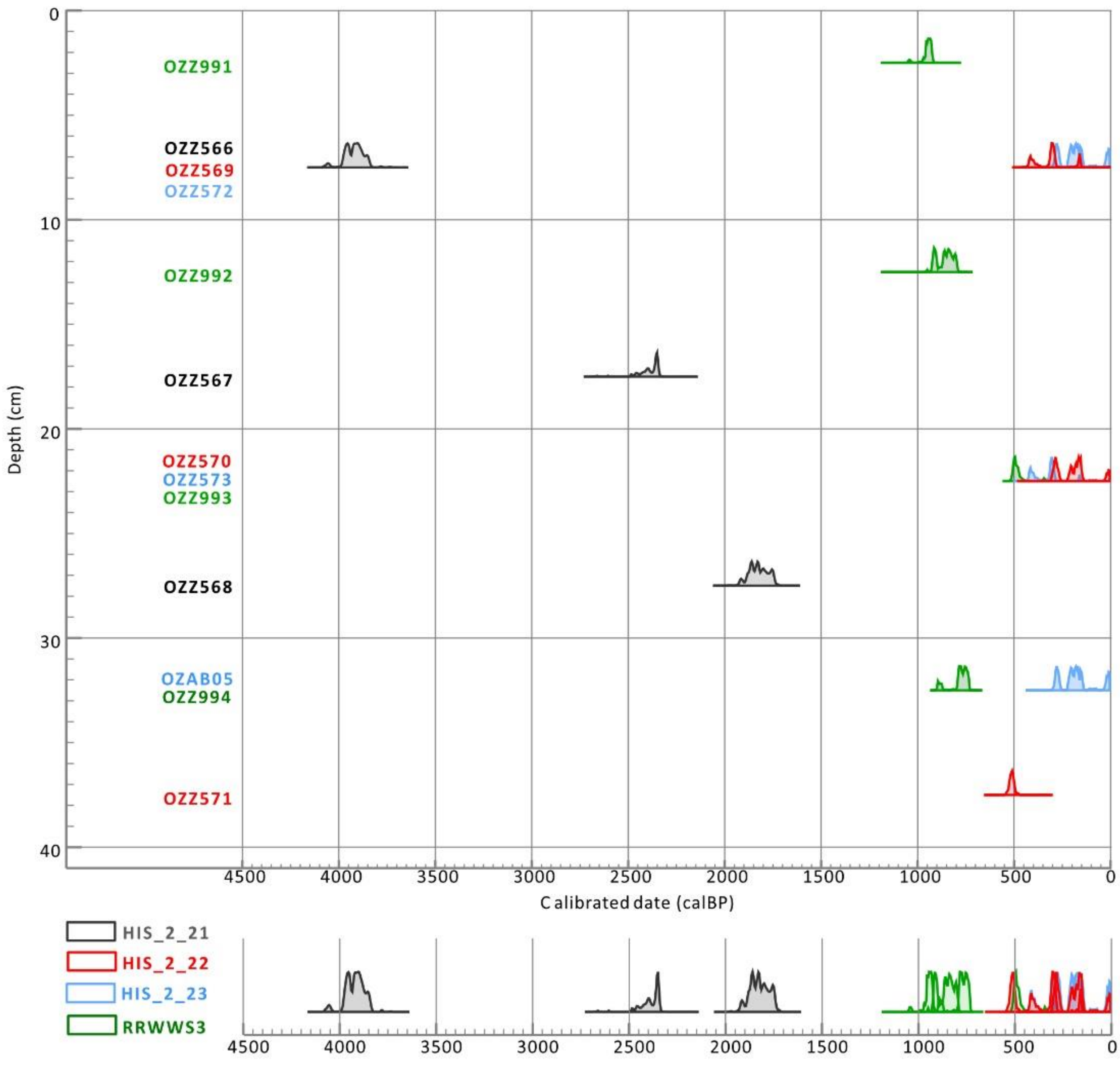


Figure 7.16: Calibrated radiocarbon age ranges (with 2 sigma errors) plotted against depth for the four lower floodplain mounds HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3 at Calperum (Jones et al. 2022).

Table 7.6: Age ranges for charcoal from the Hunchee floodplain auger samples and a surface sample of shell from mound CAPRI17_23 which was located on the western approach to Clover Lake (C. Westell pers. comm. 2021).

ID	XU/Level	Laboratory code	Depth (cm)	Sample context	Material	d^{13}C (‰)	CRA (years BP ± 1 σ error)	Calibrated Age (cal BP 95.4%)
Hunchee auger	16 cm	WK53028	16	Hunchee Floodplain	Charcoal	NA	4330+/- 21	4960–4846
Hunchee auger	57 cm	WK53029	57	Hunchee Floodplain	Charcoal	NA	2132+/- 22	2292–2004
CAPR17_23	Surface	OZX285	0	Clover Lake	Shell	-7+/-0.1	1045+/-25	960-805

small mound at Clover Lake (Figure 3.4), taken as part of a related study (Craig Westell pers. comm. 2022).

7.2.8 Plant microfossils

7.2.8.1 Pollen and starch

Table 7.7 outlines the provenance of the six mound samples analysed for plant microfossils. The results obtained from the plant microfossil analysis are presented in Figures 7.18 and 7.19. In general, the older and higher mounds yielded fewer pollen taxa per sample than the lower floodplain mounds. The majority of the pollen is represented by three taxa: Myrtaceae, Amaranthaceae and high-spine Asteraceae (Figure 7.18). Woody Myrtaceae have aromatic leaves containing oil glands and include *Eucalyptus* spp. within this family which is certainly represented in this collection of pollen. No attempt was made to differentiate below the family level for Myrtaceae pollen, due to similarities in morphology and size and the high frequency of this family in the region. It is noted that the older mounds HIS_2_21, HCN20 and HCN21 were dominated by pollen of the Amaranthaceae family in contrast to the dominance of Myrtaceae pollen in the younger mounds HIS_2_22, HIS_2_23 and RRWWS3. Larger quantities of Myrtaceae pollen suggest a more closed canopy, while increased Amaranthaceae pollen suggests more sunlight at ground level and the dominance of smaller species. HCN20 also contained a moderately large quantity of high-spine Asteraceae pollen. Concentrations of microscopic charcoal are greater in the sediment samples from mounds RRWWS3, HCN20 and HCN21 with smaller amounts in descending order from HIS_2_23, HIS_2_21 and HIS_2_22 .

The arboreal and shrubby portion of the pollen record includes small quantities of Acacia, Araliaceae, Arecaceae, *Avicennia*, Rhizophoraceae, Myrtaceae (probable *Lenwebbia* in the *Myrtaceae*) *Nerium*, Proteaceae, *Salix* and *Scaevola*. Small amounts of pollen from the mangrove genus *Rhizophora* were present in all mound samples and *Avicennia* in all except for HIS_2_23, possibly indicating long distance transport of pollen by wind from coastal habitats which contain these genera. Similarly, the presence of *Pinus* (Pine) and *Salix* (Willow) pollen suggests wind borne contamination since the introduction of *Salix* and *Pinus* species to Australia. The younger mounds are characterised by a top layer of fine, ashy and more porous, sediments (see Figure 7.17a) in contrast to a harder crust found on the Hunchee mounds which would potentially inhibit the entry and downward migration of later arrivals such as *Pinus, Salix* and *Nerium* pollen (Figure 7.17b). Though this is potentially complicated by bioturbation as indicated by the presence of *Salix* pollen at level 3 in mound HIS_2_21.

Non-arboreal pollen other than Amaranthaceae and high-spine Asteraceae (daisy/sunflower) are observed in small frequencies. Apiaceae, *Artemisia*, low-spine Asteraceae, Liguliflorae, Brassicaceae, Cyperaceae, Epachradaceae, *Euphorbia*, *Myriophyllum*, two types of Poaceae, Polygonaceae, two species of *Typha* (one that produces single pollen grains and the other that produces tetrads), and cf. *Vitex* represent members of the umbel family, sagebrush or a similar plant, ragweed or marshelder or a similar plant, a member of the chicory tribe of the sunflower family, mustards, sedges, a member of the epachris family, spurge, water milfoil, grasses, a member of the knotweed family and vitex or chaste-tree. Wetland indicators include willow, some members of the umbel family, water milfoil, some grasses, and *Typha*. Ferns are represented by small quantities of three morphotypes of spores with scalloped, reticulate, and smooth surfaces. A small quantity of scolecodonts were observed in HIS_2_22 and HIS_2_23. Spherulites were abundant in HIS_2_21, rare in HCN20, and absent in the remainder of the mounds. Spherulites are a type of microfossil that rarely survive acid processing. They are small,

Figure 7.17a: Excavation of mound RRWWS3, with members of RMMAC in attendance. Photo R. Jones October 2019.

Figure 7.17b: Photograph of the surface of mound HCN20 prior to excavation which demonstrates the hard surface crust found on this mound and HCN21.

Table 7.7: Provenance of the sediment samples provided for plant microfossil analysis.

Location	Feature	Unit	Level (Stat.)	Depth (cm)	Provenance /Description	Analysis
Lower Floodplain	HIS_2_21	SU1	3	11–15	Aboriginal earth mound Billabong levee	Pollen, Phytolith/ Starch
	RRWWS3	SU1	3	11–15	Aboriginal earth mound Billabong levee	Pollen, Phytolith/ Starch
	HIS_2_23	SU1	4	16–20	Aboriginal earth mound Billabong levee	Pollen, Phytolith/ Starch
	HIS_2_22	SU1	8	36–40	Aboriginal earth mound Billabong levee	Pollen, Phytolith/ Starch
Upper Floodplain	HCN21	SU1	4	16–20	Aboriginal earth mound Billabong levee	Pollen, Phytolith/ Starch
	HCN20	SU1	5	21–25	Aboriginal earth mound, Billabong levee	Pollen, Phytolith/ Starch

globular forms that display radial birefringent patterns. Although some forms of spherulites are observed in dung, they are not diagnostic for the presence of dung. However, the high count in HIS_2_21 likely reflects the extensive damage and bioturbation by rabbits and consequently high levels of rabbit dung within sediments. HCN20 contained a moderately large quantity of high-spine Asteraceae pollen in contrast with all other mounds.

Starches were observed in five of the six samples examined. All mound samples except for HCN20 yielded lenticular starches, which are typical of grasses with large seeds and also *Marsilea drummondi* (nardoo) and *Crinum flaccidum* (Murray Lily) both of which are species that were used by Aboriginal peoples in the MDB as a source of carbohydrate (Aston 1973:37–39; Maiden 1889:20). Starches that were spherical to sub-angular with a centric hilum were noted in the samples from RRWWS3, HIS_2_22 and HIS_2_23. Although this starch morphotype is typical of many grass seeds, it is also observed in other seeds and some tubers. The sediment from mound HCN21 provided a single small (20µ) sub-triangular fragment of starch which was slightly angular with a nearly centric or slightly eccentric hilum. At present, this specimen remains unidentified as

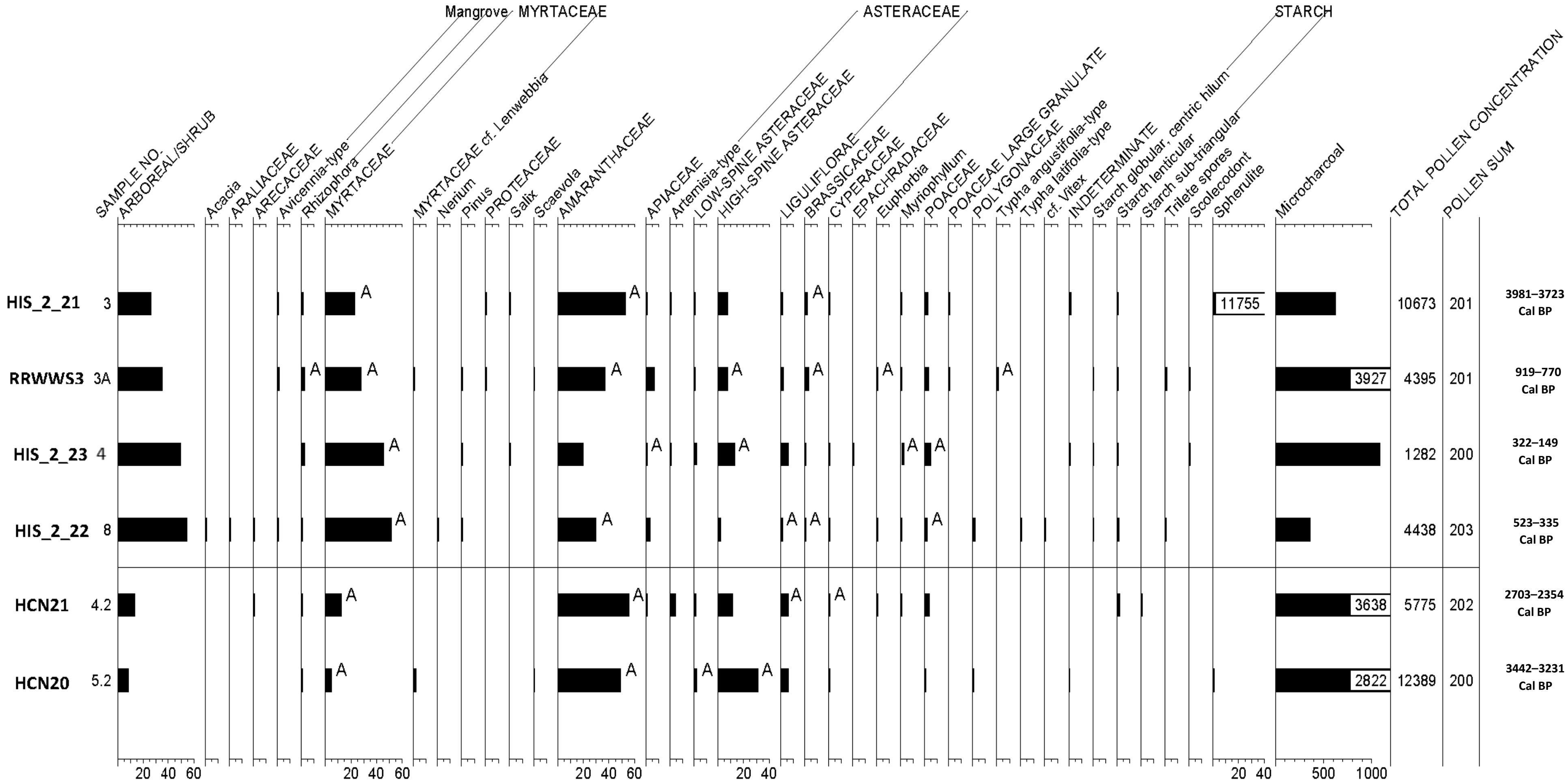


Figure 7.18: Pollen and starch study results from the six excavated mounds at Calperum. Vertical axis shows stratigraphic level from which the sample was taken (Table 7.7). Age ranges shown were obtained from shell samples in close proximity to the sediment samples used for the pollen and phytoliths studies.

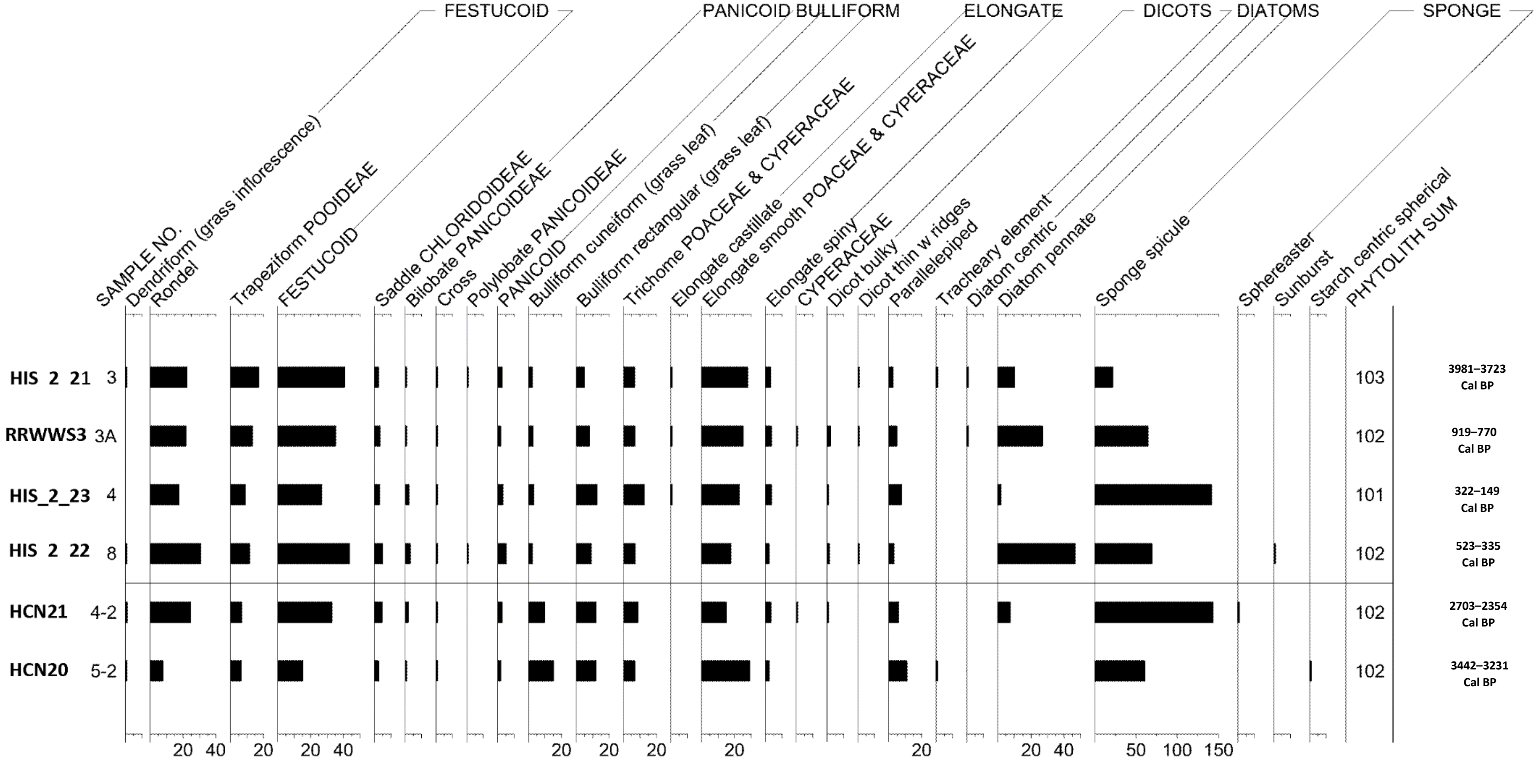


Figure 7.19: Phytolith, diatom and sponge study results. Age ranges shown were obtained from shell samples in close proximity to the sediment samples used for the pollen and phytoliths studies.

it is not large enough to adequately match with reference samples. A single centric starch, typical of grass seeds, was observed in sample HCN20.

7.2.8.2 Phytoliths

The phytolith record is dominated by Festucoid phytoliths including dendriforms, rondels, and trapeziforms (Figure 7.19), representing cool season grasses. This class of phytoliths is more abundant in the lower floodplain mounds than the two older mounds located on the northern bank of Hunchee creek on the higher floodplain. Slightly higher quantities of bulliforms and elongates were observed in the sediments of the older mounds from the higher floodplain. Bulliforms and elongates are typical of grasses, but cannot be used to identify any particular type of grass. Grass short cells are more prone to dissolution because they are smaller in size than the larger, more general forms such as bulliforms. Saddle-shaped Chloridoid phytoliths represent warm season, short grasses. They are present in all samples, but not particularly abundant. Panicoid phytoliths include bilobates and crosses, present in all samples, and a few polylobates. Bulliforms, trichomes and all forms of elongates, are generalised forms that do not contribute to an interpretation of the types of grasses growing locally. Cyperaceae phytoliths were noted in mounds RRWWS3 and HCN21, suggesting sedges grew in the vicinity of the mounds. Phytoliths typical of dicotyledonous (dicot) plants were observed in all samples, although they were not sufficiently diagnostic to contribute to understanding the local vegetation community. A single body described as a sunburst shape recovered in mound HIS_2_22 probably represents silicified plant hairs.

Pennate diatoms were noted in widely varying frequencies in five of the six mound samples examined. Sponge spicules were observed in all six samples, providing a significant wetland signature for these mound deposits.

7.2.9 Elemental, pH and colour analysis

The concentrations of elements of interest in this study were obtained from the pXRF/ICP-MS analysis of the six excavated mound sediments and are presented in Tables 7.8a, b., 7.10, 7.11 and 7.12a, b. Table 7.9 provides the same elemental (pXRF)profile for the Hunchee auger sediment samples. Of the elements selected, P is considered to be an anthropogenic signal related to the cooking of plant material in earth mounds and consequently present in mound sediments (Cuenca-Garcia 2015:220; Williams et al. 2020), in a floodplain context Cl is an environmental signature of the presence of saline ground water (Murray Darling Basin Authority 2022), Ca is associated with the residues of wood burning and may reflect burning intensity and/or taphonomic influences over time in a stratigraphic context (Cuenca-Garcia 2015:220). Ba is a potential environmental signature associated with flooding (Dalai et al. 2002; Wolgemuth and Broecker 1970:375). pH values and the colour of sediment for each excavation level was determined through the use of an Munsell colour chart and a soil pH meter PH220S-KIT. A comparison of this data with pXRF concentrations for P, Ca and Cl is presented in Table 7.10.

7.2.10 Elemental, pH and colour patterns

The pXRF data obtained from the Bruker Tracer i5 device across repeated calibration determinations indicated good correlation with Ca and K but higher variation and error with Ba, P and Cl (Table 7.8b). Calibration run two was an outlier and was discounted. The results allow the consideration of trending and non-trending data and comparisons across mounds (Tables 7.8a, 7.12a, b). Mound HIS_2_21 demonstrates relatively homogenous values of P and Ca across all levels (P ranges 1180–1448 ppm [pXRF] and 977–1434 [ICP-MS]; and Ca ranges 35473–55353 [pXRF] and 23004–39572 [ICP-MS]. All other mounds show a relative decline in P and Ca concentration with depth. Mounds HIS_2_22 and RRWWS3 demonstrate a similar pattern of Cl and Na concentration—relatively high and declining with depth which is significantly different to the four other mounds, albeit at a high level of error for the pXRF method. All other mounds show low or static values of chloride and Na with depth. Mounds HIS_2_22 and RRWWS3 also show a decline in Ba concentration at the 4/5 level. This coincided with a layer of sand in RRWWS3 and an increase in grain size at this level in both of these mounds (see figures 7.7c and 7.5). Mounds HIS_2_21, HIS_2_23, HCN20 and HCN21 have pH values in the very alkaline range (8 to 9.6), in contrast to RRWWS3 and HIS_2_22 which have ranges from 6.5 to 7.7 and 7.7 to 8.0 respectively.

The Munsell colour system trends darker with a decrease in value in the second to last number (e. g., 7.5YR5/1 to 7.5YR4/1 to 7.5YR3/1). Mound HIS_2_21 displayed a slight transition from brown to gray with increasing depth except for level 3 which was a very dark gray. Mound HIS_2_22 had a uniform colour of very dark gray through all levels. Mound HIS_2_23 was uniformly dark gray over all levels apart from a slight difference in hue at level 7. Mound RRWWS3 was very dark gray over levels 1–6 and levels 7 and 8 were black, with

Table 7.8a: Sediment elemental concentration (ppm) by the pXRF method and related radiocarbon dates for excavated mounds. Specific readings showing trends and anomalies of interest as outlined in the text are highlighted in yellow. Ages derived from charcoal are marked 'c'.

Sample ID	P (ppm)	P Err.	Cl (ppm)	Cl Err.	Ca (ppm)	Ca Err.	Ba (ppm)	Ba Err.	Age range cal BP
HIS_2_21_L1	1415	205	369	1209	35473	216	2653	2480	**3981–3723**
HIS_2_21_L2	1442	213	196	1231	43313	237	1990	2475	
HIS_2_21_L3	1448	221	28	1224	50072	255	234	2339	
HIS_2_21_L4	1131	214	1545	1292	54614	265	633	2409	**2429–2150**
HIS_2_21_L5	1211	214	1834	1346	55353	266	1188	2404	
HIS_2_21_L6	1180	211	1785	1389	49030	251	1873	2481	**1864–1729**
HIS_2_22_L1	2789	252	5447	1461	56378	269	462	2288	
HIS_2_22_L2	2851	265	8605	1706	71873	302	904	2345	**321–144**
HIS_2_22_L3	1806	211	5649	1704	56197	264	1006	2271	
HIS_2_22_L4	3512	279	8210	1706	82137	322	1094	2335	
HIS_2_22_L5	3509	276	6606	1538	71773	302	58	2334	**295–0**
HIS_2_22_L6	3213	258	5821	1451	49994	254	691	2355	
HIS_2_22_L7	2315	232	5019	1498	42174	234	283	2372	
HIS_2_22_L8	1091	172	4271	1484	19435	160	796	2264	**523–335**
HIS_2_22_L9	1794	210	4722	1519	31197	202	0	2465	
HIS_2_23_L1	2241	237	0	1213	53766	262	1258	2491	
HIS_2_23_L2	2690	255	0	1183	62903	283	2241	2408	**283–0**
HIS_2_23_L3	2671	267	0	1301	86101	329	732	2456	
HIS_2_23_L4	2482	253	466	1210	66959	292	1523	2460	
HIS_2_23_L5	2112	226	657	1253	43465	237	1399	2486	**322–149**
HIS_2_23_L6	1929	215	333	1224	32893	208	710	2480	
HIS_2_23_L7	1660	209	173	1255	34066	211	895	2473	**283–59**
RRWWS3_L1	1156	188	13225	1747	26554	187	834	2441	**960–805**
RRWWS3_L2	1307	187	8666	1551	20801	167	835	2419	
RRWWS3_L3	1036	177	9111	1575	20507	165	1960	2464	**919–770**
RRWWS3_L4	1032	179	5660	1459	18204	157	0	2407	
RRWWS3_L5	717	168	6111	1449	17775	155	785	2449	**500–327c**
RRWWS3_L6	560	167	6363	1470	18924	160	751	2439	
RRWWS3_L7	560	158	6096	1502	16751	151	586	2339	**793–685c**
RRWWS3_L8	453	154	5646	1412	15584	146	1009	2352	
HCN20_L1	2414	247	160	1165	54584	264	13	2404	
HCN20_L2	2444	251	0	1175	61157	280	1067	2452	**296–32/461–306c**
HCN20_L3	2258	244	0	1221	62588	283	1325	2477	
HCN20_L4	1940	234	0	1209	54907	266	1110	2483	**3700–3452/3618–3396**
HCN20_L5	1603	222	0	1161	50898	256	2525	2531	
HCN20_L6	1369	210	0	1231	45389	242	1522	2500	**3442–3231/502–326c**
HCN20_L7	552	159	170	1249	25018	180	581	2274	**280–0c**
HCN21_L1	2483	254	0	1227	67734	292	1005	2430	**922–770**
HCN21_L2	1649	219	611	1233	44965	240	741	2472	
HCN21_L3	1129	191	1211	1269	30406	199	912	2460	**2703–2354/727–570c**
HCN21_L4	1234	194	303	1112	25369	184	356	2458	
HCN21_L5	631	169	495	1135	22569	173	466	2256	
HCN21_L6	698	171	77	1103	22013	171	1510	2448	**4404–4092/4418–4158c**
HCN21_L7	613	161	142	1086	21156	168	1331	2526	
HCN21_L8	535	161	1004	1138	17909	155	1479	2515	
HCN21_L9	484	160	104	1079	17764	155	1466	2218	**4803–4423c/4807–4442c**

the latter displaying a difference in hue. Mound HCN20 was very dark gray and dark gray at levels 1 and 2 respectively, then lighter in colour with grayish brown from levels 3 to 7. Mound HCN21 was grayish brown at level 1, dark grayish brown at levels 2 and 3, then brown to grayish brown over levels 4 to 6 and light brownish gray over levels 7 to 9.

The elemental concentration profiles shown in the off mound auger samples (Table 7.9) are significantly different to the patterns demonstrated in the mound sediments, indicating the difference between anthropogenic and natural processes. For example, P is totally absent from the auger sediments with little change in the concentration of all elements and an unusually high reading for Ca at 77 cm. pH for samples from all auger levels were close to neutral which was lower than all mounds except for RRWWS3 and HIS_2_22 (Table 7.11).

Table 7.8b: Repeat pXRF calibration data for five selected elements using the OREAS 45d Standard.

Element			P (ppm)	Err.	Cl (ppm)	Err.	Ca (ppm)	Err.	Ba (ppm)	Err.	K (ppm)	Err.
Standard			420		60		1850		183		4120	
Calibration Run	1	21/10/2021	95	83	0	651	1714	38	484	1279	3503	58
	2	21/10/2021	610	169	151	1108	9875	126	517	2268	6297	126
	3	21/10/2021	158	151	0	1107	1696	67	533	2264	3898	106
	4	21/10/2021	237	159	0	1003	1861	69	881	2281	4030	107
	5	21/10/2021	213	156	25	1080	1757	68	1038	2276	4027	107
	6	21/10/2021	170	158	0	1090	1803	68	1128	2264	4029	107
	7	21/10/2021	264	154	0	1063	1794	68	223	2247	3998	107
	8	21/10/2021	228	156	540	1066	1778	68	275	2245	3939	106
	9	23/09/2021	191	151	0	1092	1716	67	486	2196	3981	106
	10	23/09/2021	185	152	173	1083	1686	67	0	2189	3782	106
	11	24/08/2021	346	154	0	1101	1752	67	1148	2300	3918	105
	12	24/08/2021	240	153	0	1092	1733	67	337	2273	3899	105
		Atomic No.	15		17		20		56		19	

Table 7.9: Selected element concentration (ppm) (pXRF) in sediment from the Hunchee floodplain auger samples.

ID	P (ppm)	Err.	Cl (ppm)	Err.	Ca (ppm)	Err.	Ba (ppm)	Err.
CAI	346	154	0	1101	1752	67	1148	2300
HA-016	0	91	0	2111	1775	72	2561	3260
HA-019	0	91	0	2127	1657	69	2217	3166
HA-027	0	89	0	2039	1460	68	2237	3075
HA-042	0	94	0	2099	2111	74	1713	3210
HA-057	0	88	48	2033	1550	67	3674	3019
HA-077	0	100	0	1899	11083	128	1368	2641

Table 7.10: Comparison of sediment colour, pH data and P, C and Cl concentrations (pXRF) for all mound levels. Data values and trends which were determined to be of interest for this study are highlighted in yellow.

Sample ID	pH	Colour reading	Colour	pXRF P (ppm)	pXRF Ca (ppm)	pXRF Cl (ppm)
HIS_2_21_L1	9.2	7.5 YR 4/2	Brown	1415	35473	369
HIS_2_21_L2	8.7	7.5 YR 4/1	Dark gray	1442	43313	196
HIS_2_21_L3	8.7	7.5 YR 3/1	Very dark gray	1448	50072	28
HIS_2_21_L4	8.5	7.5 YR 5/1	Gray	1131	54614	1545
HIS_2_21_L5	9.0	7.5 YR 5/1	Gray	1211	55353	1834
HIS_2_21_L6	9.0	7.5 YR 5/1	Gray	1180	49030	1785
HIS_2_22_L1	8.0	7.5 YR 3/1	Very dark gray	2789	56378	5447
HIS_2_22_L2	8.0	7.5 YR 3/1	Very dark gray	2851	71873	8605
HIS_2_22_L3	8.0	7.5 YR 3/1	Very dark gray	1806	56197	5649
HIS_2_22_L4	8.0	7.5 YR 3/1	Very dark gray	3512	82137	8210
HIS_2_22_L5	7.8	7.5 YR 3/1	Very dark gray	3509	71773	6606
HIS_2_22_L6	7.6	7.5 YR 3/1	Very dark gray	3213	49994	5821
HIS_2_22_L7	7.6	7.5 YR 3/1	Very dark gray	2315	42174	5019
HIS_2_22_L8	7.5	7.5 YR 3/1	Very dark gray	1091	19435	4271
HIS_2_22_L9	7.7	7.5 YR 3/1	Very dark gray	1794	31197	4722
HIS_2_23_L1	8.8	7.5 YR 4/1	Dark gray	2241	53766	0
HIS_2_23_L2	9.0	7.5 YR 4/1	Dark gray	2690	62903	0
HIS_2_23_L3	9.5	7.5 YR 4/1	Dark gray	2671	86101	0
HIS_2_23_L4	9.5	7.5 YR 4/1	Dark gray	2482	66959	466
HIS_2_23_L5	9.4	7.5 YR 4/1	Dark gray	2112	43465	657
HIS_2_23_L6	7.8	7.5 YR 4/1	Dark gray	1929	32893	333
HIS_2_23_L7	8.4	10 YR 4/1	Dark gray	1660	34066	173
RRWWS3_L1	7.7	7.5 YR 3/1	Very dark gray	1156	26554	13225
RRWWS3_L2	7.5	7.5 YR 3/1	Very dark gray	1307	20801	8666
RRWWS3_L3	7.2	7.5 YR 3/1	Very dark gray	1036	20507	9111
RRWWS3_L4	7.2	7.5 YR 3/1	Very dark gray	1032	18204	5660
RRWWS3_L5	7.2	7.5 YR 3/1	Very dark gray	717	17775	6111
RRWWS3_L6	6.9	7.5 YR 3/1	Very dark gray	560	18924	6363
RRWWS3_L7	7.0	7.5 YR 2.5/1	Black	560	16751	6096
RRWWS3_L8	6.5	10 YR 2/1	Black	453	15584	5646
HCN20_L1	9.0	10 YR 3/1	Very dark gray	2414	54584	160
HCN20_L2	9.6	10 YR 4/1	Dark gray	2444	61157	0
HCN20_L3	9.0	10 YR 5/2	Grayish-brown	2258	62588	0
HCN20_L4	8.5	10 YR 5/2	Grayish-brown	1940	54907	0
HCN20_L5	9.5	10 YR 5/2	Grayish-brown	1603	50898	0
HCN20_L6	8.0	10 YR 5/2	Grayish-brown	1369	45389	0
HCN20_L7	9.0	10 YR 5/2	Grayish-brown	552	25018	170
HCN21_L1	9.6	10 YR 5/2	Grayish brown	2483	67734	0
HCN21_L2	9.5	10 YR 4/2	Dark gray-brown	1649	44965	611
HCN21_L3	9.5	10 YR 4/2	Dark gray-brown	1129	30406	1211
HCN21_L4	9.0	10 YR 4/3	Brown	1234	25369	303
HCN21_L5	8.5	10 YR 5/2	Grayish-brown	631	22569	495
HCN21_L6	8.0	10 YR 5/2	Grayish-brown	698	22013	77
HCN21_L7	8.0	10 YR 6/2	L. brown-gray	613	21156	142
HCN21_L8	8.0	10 YR 6/2	L. brown-gray	535	17909	1004
HCN21_L9	8.5	10 YR 6/2	L. brown-gray	484	17764	104

Table 7.11: pH, colour and physical characteristics of the Hunchee floodplain auger samples.

ID	pH	Colour reading	Colour	Comment
HA-016	7.7	5YR 6/1	Light gray	Fine to small nodules
HA-019	7.2	5YR 6/1	Light gray	Fine to small nodules
HA-027	7.2	5YR 5/1	Light gray	Fine to small nodules
HA-042	7.0	5YR 5/1	Light gray	Larger shiny nodules
HA-057	7.1	5YR 4/1	Darker gray	Larger shiny nodules
HA-077	7.5	5YR 4/1	Darker gray	Larger, dense, shiny nodules

Sediment was relatively uniform in colour with a trend to darker gray and higher moisture and density with depth.

7.2.13 ICP-MS analysis

As outlined in section 6.2.7 above, the ICP-MS method was adopted to assess the trends observed in the pXRF data for the mound sediments due to the error level associated with the pXRF method. The results and comparisons are outlined in Table 7.12a and 7.12b respectively. The elements with lower pXRF error levels such as P and Ca generally show the same trend in both methods but with some variation in numerical value (Table 12.b). Trend correlation is most apparent in mounds HCN20 and HCN21 for P and Ca and less in mound RRWWS3. Ba shows no reliable correlation other than a weak in that element at level 4 in both HIS_2_22 and RRWWS3. The latter mound shows a layer of coarser sediment potentially associated with a flooding event at that level (Figures 7.5 and 7.6).

Table 7.12a:Selected elemental concentrations (ppm) and corresponding error for the earth mound sediments via the ICP-Ms method.

Sample ID	ICP-MS P (ppm)	ICM-MS P Err. (ppm)	ICP-MS Ca (ppm)	ICP-MS Ca Err. (ppm)	ICP-MS Ba (ppm)	ICP-MS Ba Err. (ppm)	ICP-MS Na (ppm)	ICP-MS Na Err. (ppm)
HIS_2_21_L1	1027	2.8	23004	3.1	128	1.5	1236	3.1
HIS_2_21_L2	1273	2.8	35734	3.2	173	2.0	1144	1.5
HIS_2_21_L3	979	1.5	29907	3.6	111	0.1	959	4.6
HIS_2_21_L4	977	3.3	33400	3.3	115	1.2	1031	4.7
HIS_2_21_L5	1434	2.9	39572	2.5	134	1.9	1126	3.9
HIS_2_21_L6	1129	2.5	39331	4.2	129	0.8	1347	4.1
HIS_2_22_L1	1428	1.9	26008	4.1	154	0.5	1717	3.2
HIS_2_22_L2	1569	1.5	32944	4.0	145	0.4	2155	3.6
HIS_2_22_L3	1935	2.1	40661	3.4	180	0.6	3173	5.3
HIS_2_22_L4	2099	3.2	49160	1.9	181	2.2	3127	3.4
HIS_2_22_L5	1737	1.1	37331	4.2	148	1.0	2865	5.2
HIS_2_22_L6	1765	2.2	30185	1.9	159	1.8	2900	2.8
HIS_2_22_L7	1308	2.7	20731	3.0	136	0.5	2337	4.4
HIS_2_22_L8	764	1.1	12602	3.2	325	1.2	2246	3.6
HIS_2_22_L9	1011	2.6	15735	3.0	187	1.3	2225	3.1
HIS_2_23_L1	1103	2.4	21775	2.7	101	2.1	480	3.5
HIS_2_23_L2	1449	1.7	34230	3.0	122	0.7	842	2.3
HIS_2_23_L3	2486	1.0	58632	4.2	163	1.1	1139	2.3
HIS_2_23_L4	1604	1.7	37932	3.1	133	0.9	931	3.9
HIS_2_23_L5	1454	1.1	24983	4.2	120	0.5	879	3.0
HIS_2_23_L6	1517	1.6	17926	3.3	142	0.6	784	4.2
HIS_2_23_L7	1429	1.3	19841	3.9	174	1.0	747	3.4
RRWWS3_L1	778	1.0	12924	3.0	125	1.0	4243	4.8
RRWWS3_L2	557	2.2	7980	4.1	129	1.5	4036	3.2
RRWWS3_L3	760	2.2	11346	3.6	182	1.1	5308	4.6
RRWWS3_L4	513	1.9	8764	3.9	128	1.3	4331	3.7
RRWWS3_L5	607	2.1	10371	3.2	158	0.7	5481	1.5
RRWWS3_L6	530	3.0	8577	2.2	145	1.0	5117	3.6
RRWWS3_L7	607	1.1	9182	4.2	109	0.9	3206	4.8
RRWWS3_L8	863	1.1	12175	4.4	130	0.4	4368	4.3
HCN20_L1	2127	1.8	53494	2.0	175	0.4	1300	2.4
HCN20_L2	2303	0.9	60788	5.4	167	1.2	1297	3.3
HCN20_L3	2110	1.3	54862	2.3	148	0.2	1771	4.5
HCN20_L4	2159	1.2	60997	3.1	159	1.4	2111	5.0
HCN20_L5	1662	2.2	51633	3.3	139	0.7	1844	2.7
HCN20_L6	1425	1.2	52091	2.3	140	0.5	1497	3.9
HCN20_L7	794	2.9	37217	1.7	222	1.3	1339	4.1
HCN21_L1	1958	1.9	55973	2.5	159	0.3	1738	3.7
HCN21_L2	1906	1.2	31269	2.9	129	0.5	1732	4.2
HCN21_L3	801	3.3	19199	2.6	62	1.5	1462	3.0
HCN21_L4	1776	3.5	22804	3.1	81	1.1	1604	3.6
HCN21_L5	634	0.2	16224	4.2	82	1.7	1459	3.8
HCN21_L6	503	2.7	13683	3.6	77	0.8	1111	2.6
HCN21_L7	1396	2.0	54008	2.3	168	1.5	1477	3.0
HCN21_L8	214	1.7	6084	4.6	38	0.8	726	3.4
HCN21_L9	230	2.8	6314	2.5	96	1.1	796	4.5

Table 7.12b: Comparison of selected sediment elemental concentrations (ppm) for excavated mounds from the pXRF and ICP-MS methods. Note that Cl was not included in the ICP-MS analysis so Na was included for comparison with pXRF Cl results. Sodium was selected for comparison with pXRF Cl results due to their association in salt (NaCl). Yellow denotes trends and associations of interest as discussed in the text.

Sample ID	pXRF P (ppm)	ICP-MS P (ppm)	pXRF Ca (ppm)	ICP-MS Ca (ppm)	pXRF Ba (ppm)	ICP-MS Ba (ppm)	pXRF Cl (ppm)	ICP-MS Na (ppm)
HIS_2_21_L1	1415	1027	35473	23004	2653	128	369	1236
HIS_2_21_L2	1442	1273	43313	35734	1990	173	196	1144
HIS_2_21_L3	1448	979	50072	29907	234	111	28	959
HIS_2_21_L4	1131	977	54614	33400	633	115	1545	1031
HIS_2_21_L5	1211	1434	55353	39572	1188	134	1834	1126
HIS_2_21_L6	1180	1129	49030	39331	1873	129	1785	1347
HIS_2_22_L1	2789	1428	56378	26008	462	154	5447	1717
HIS_2_22_L2	2851	1569	71873	32944	904	145	8605	2155
HIS_2_22_L3	1806	1935	56197	40661	1006	180	5649	3173
HIS_2_22_L4	3512	2099	82137	49160	1094	181	8210	3127
HIS_2_22_L5	3509	1737	71773	37331	58	148	6606	2865
HIS_2_22_L6	3213	1765	49994	30185	691	159	5821	2900
HIS_2_22_L7	2315	1308	42174	20731	283	136	5019	2337
HIS_2_22_L8	1091	764	19435	12602	796	325	4271	2246
HIS_2_22_L9	1794	1011	31197	15735	0	187	4722	2225
HIS_2_23_L1	2241	1103	53766	21775	1258	101	0	480
HIS_2_23_L2	2690	1449	62903	34230	2241	122	0	842
HIS_2_23_L3	2671	2486	86101	58632	732	163	0	1139
HIS_2_23_L4	2482	1604	66959	37932	1523	133	466	931
HIS_2_23_L5	2112	1454	43465	24983	1399	120	657	879
HIS_2_23_L6	1929	1517	32893	17926	710	142	333	784
HIS_2_23_L7	1660	1429	34066	19841	895	174	173	747
RRWWS3_L1	1156	778	26554	12924	834	125	13225	4243
RRWWS3_L2	1307	557	20801	7980	835	129	8666	4036
RRWWS3_L3	1036	760	20507	11346	1960	182	9111	5308
RRWWS3_L4	1032	513	18204	8764	0	128	5660	4331
RRWWS3_L5	717	607	17775	10371	785	158	6111	5481
RRWWS3_L6	560	530	18924	8577	751	145	6363	5117
RRWWS3_L7	560	607	16751	9182	586	109	6096	3206
RRWWS3_L8	453	863	15584	12175	1009	130	5646	4368
HCN20_L1	2414	2127	54584	53494	13	175	160	1300
HCN20_L2	2444	2303	61157	60788	1067	167	0	1297
HCN20_L3	2258	2110	62588	54862	1325	148	0	1771
HCN20_L4	1940	2159	54907	60997	1110	159	0	2111
HCN20_L5	1603	1662	50898	51633	2525	139	0	1844
HCN20_L6	1369	1425	45389	52091	1522	140	0	1497
HCN20_L7	552	794	25018	37217	581	222	170	1339
HCN21_L1	2483	1958	67734	55973	1005	159	0	1738
HCN21_L2	1649	1906	44965	31269	741	129	611	1732
HCN21_L3	1129	801	30406	19199	912	62	1211	1462
HCN21_L4	1234	1776	25369	22804	356	81	303	1604
HCN21_L5	631	634	22569	16224	466	82	495	1459
HCN21_L6	698	503	22013	13683	1510	77	77	1111
HCN21_L7	613	1396	21156	54008	1331	168	142	1477
HCN21_L8	535	214	17909	6084	1479	38	1004	726
HCN21_L9	484	230	17764	6314	1466	96	104	796

7.2.12: Gradiometric prospection in the vicinity of mound HIS_2_23

An area immediately to the south of mound HIS_2_23 which contained several stone artefacts (Appendix Eight) was selected for a gradiometric study to assess the possibility of camp sites near earth mounds located on the Calperum floodplain (Figure 7.20).

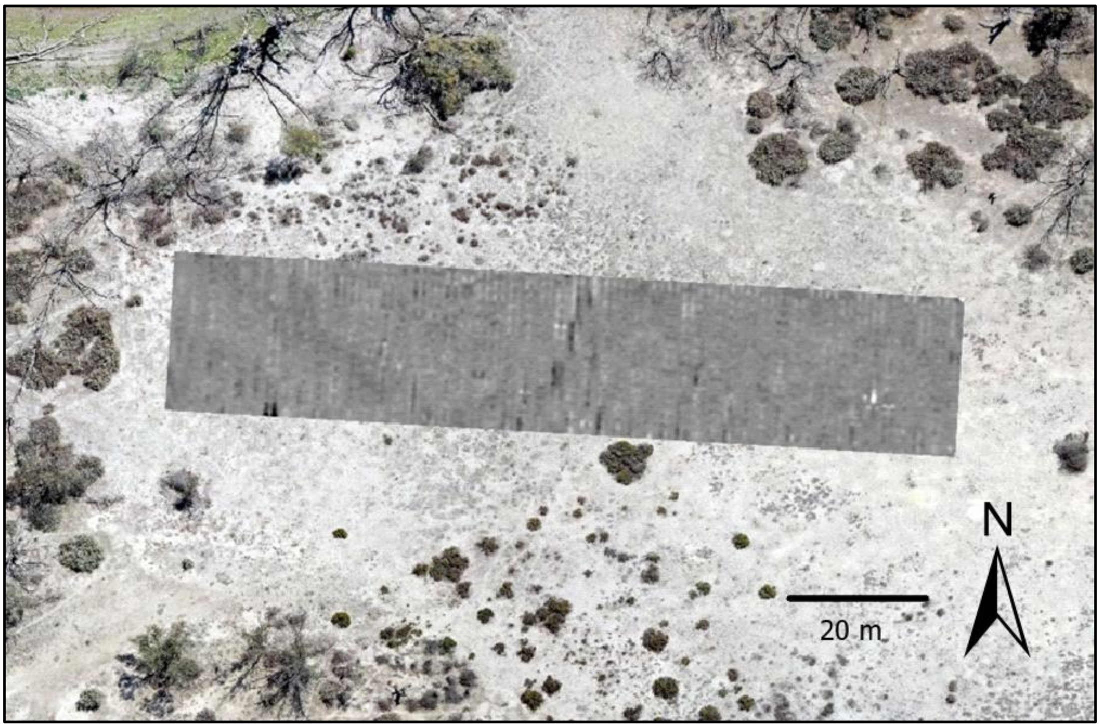


Figure 7.20: Image from the gradiometric study conducted south-west of mound HIS_2_23 (located top right in the image). Gradiometric data is displayed using +/- 2nT scale.

The image shows no evidence of sub-surface combustion features.

7.3 Chapter summary

The results from the methods deployed in this study constitute the output of the first integrated study of a set of Australian Aboriginal earth mounds located in a multi-contextual floodplain environment. The integration of contents analysis, radiocarbon dating, plant microfossils and sediment analyses has provided new data for the evaluation of earth mounds as potential palimpsests of information about socio-cultural change in Aboriginal groups living in these environments from the mid Holocene. The discussion follows in Chapter Eight.

Chapter Eight: Discussion

8.1 Introduction

The purpose of this chapter is to discuss the results obtained from the earth mound analyses with reference to the research question and aims posed in Chapter one.

The research question posed by this thesis is:

How can the archaeology of Aboriginal earth mounds contribute to debates concerning Aboriginal socio-economic practices in wetland environments of the Riverland region and in the MDB more widely, and how does this earth mound archaeology relate to the purported introduction of BSD in Australia during the mid to late Holocene?

The stated research aims were:

1. To review the available literature on Australian oven mounds and associated resource procurement strategies to define the ecological precincts and local situational contexts where Australian Aboriginal earth oven mounds were established.
2. To investigate the composition (micro and macro) of earth mound sediments located on the Calperum floodplain including faunal and botanical remains, artefacts and trends over time.
3. To establish and investigate the chronological context of earth mounds on the Calperum floodplain in relation to published chronological, environmental and climatic data from the mid to late Holocene.
4. To consider and comment on the principal theoretical frameworks relevant to the analysis and reporting of this work in order to explore environmental and socio-economic factors relating to the creation of earth mounds; and,
5. To consider whether the data and analysis derived from this project supports the purported emergence of BSD in Australia.

8.2 Chapter structure

This chapter is structured to provide the following:

- A comparison of Calperum earth mounds to other sites in Australia;
- A discussion of the results obtained from the excavation and various analyses of the contents and sediments of the six Calperum mounds included in this study;
- A consideration of evidence for the impact of climate and ecological change on earth mound proliferation at Calperum; and,
- A consideration of intensification theory, BSD and the role of innovation in relation to the evidence from Calperum.

8.3 The relationship of the Calperum earth mounds to prior studies

Chapters Three and Four of this thesis provided a review of the research literature concerning the chronology, morphology, functions and situational contexts of Australian Aboriginal earth mounds including an examination of the surrounding geographic, environmental and resource contexts within which they occur. The examination of ethnohistorical and archaeological evidence of subsistence practices in Australian earth mound precincts and other regions, has demonstrated the ubiquitous nature of earth oven use for cooking animal and plant foods by Aboriginal peoples (Allen 1998; Bowler et al. 1970; Brockwell et al. 2011; Cupper and Duncan 2006; Holdaway et al. 2002:352–354; Isaacs 1989:54-55; McConnel 1930:103; Morrison et al. 2022; Pardoe 2003; Sutton 1994:44; Thomson 1939:220–221; Veth et al. 1990; von Sturmer 1978; Wallis et al. 2004; Whitau et al. 2018). Furthermore, the use of heat retainer technology has been shown to have a deep history of use in Australia and in global contexts (Black and Thoms 2014; Clarkson et al. 2017; Florin et al. 2020; Salazar et al. 2012; Thoms 2015; Whitau et al. 2018). The evidence has indicated that Australian earth mounds are created by the repeated use of earth ovens in the same location and occur within wetland areas in two different environmental zones, with similar age ranges for the earliest mounds dated in each. The earliest dates for earth mounds in these regions are 5319–4425 cal BP (WK-4101) and 5054–4390 cal BP (ANU-3992) for the western Hay Plain region of the MDB and the South Alligator River region of the Northern Territory respectively (Martin 2006, 2011; Woodroofe et al. 1988). The two climate zones are the temperate south-eastern portion of the continent including the riverine wetlands of the MDB, the northern Adelaide Plains and western Victoria; and the northern tropical zone, including the coastal regions of the Northern Territory and the west coast of northern Cape York in North Queensland (Balme and Beck 1996; Berryman and Frankel 1984; Brockwell 2006; Brockwell et al. 2017; Coutts et al 1976, 1979, 1980; Frankel 1991; Godfrey et al. 1996; Johnston 2004; Jones 2016; Jones et al. 2017, 2022; Klaver 1998; Lane 1980; Martin 2006; Ó Foghlú 2017; Pardoe and Hutton 2020; Sullivan 1980; Westell and Wood 2014; Williams 1988).

The mounds exhibit considerable variation in age, span of use, morphology, contents and placement, likely due to differences in location, climate and the variety of subsistence resources cooked within them (Brockwell 2006; Coutts 1976, 1979; Jones et al. 2017; Jones et al. 2022; Martin 2006; Klaver 1998; Ó Foghlú 2017, 2021; Pardoe 2003; Pardoe and Hutton 2020). For instance, in riverine environments of the MDB they were likely initiated as a single focus cooking site (e. g., for cooking large quantities of aquatic plant roots) but occasionally individual mounds were further developed and used as seasonal occupation sites during periods of flooding, to enable continued access to wetland resources (Coutts 1976, 1979; Jones et al. 2022; Westell and Wood 2014; see also Table 2.1 and Klaver 1998:122–135 for an indication of diversity of fire related features in this context). In these latter instances, mounds were found to contain more archaeological materials, including burials, the remnants of wood and foliage used for shelters and faunal remains (Coutts et al. 1976, 1979). Mounds located in the northern Adelaide Plains and some locations in western Victoria were similarly associated with a wider range of archaeological materials suggesting more general use as occupation space rather than single purpose cooking sites (Littleton et al. 2013; Westell and Wood 2014; Williams 1988). In the Northern Territory, the archaeological record indicates Aboriginal groups who created earth mounds in riverine environments cooked a wide range of locally available seasonal resources in the ovens, including both animal and plant foods (Brockwell 2001b, 2006, 2009; Guse 2005:89–90, 2006; Peterson 1973:173–186).

The key functional criterion linking the mounds of these diverse floodplain environments are seasonal changes in subsistence resources due to significant hydrological events, either from a 'tropical wet season' (in the north of the continent) or a seasonal flooding (floodplain recharging) event delivered by a river system (some locations in southern Australia).

The mounds found at Calperum Station do not contain material indicative of use as living spaces such as high amounts of shell, animal bone, stone artefacts and possibly burials.

Their location, ages, morphology and contents indicate the continued use of earth ovens in specific locations over extended periods of time for the exploitation of seasonally abundant food resources such as roots derived from emergent macrophytes. Earth-oven cookery, especially for bulk processing, storage or immediate communal consumption, was described by Lewis Binford (1983:168) as ‘dirty’ work usually undertaken well-removed from residential structures and core residential activities. The relatively close proximity of suitable residential areas free from inundation except in extreme instances is characteristic of the mounds located within the Calperum floodplain (see Figure 6.1c for an example).

The initial analysis of mound morphology and the absence of surface material culture during surveys conducted at Calperum showed that mounds probably represent seasonal cooking sites in use over extended periods. It was considered that the mounds would potentially provide the basis for an integrated study of past socio-economic practices in a wetland environment of the MDB via the analysis of contents, sediments and chronology (Jones 2016; Jones et al. 2017, 2022; Thredgold et al. 2017; Ross et al. 2019). Consequently, the six Calperum mounds excavated for this study were chosen and investigated on the basis of the local environment and mound morphology. The locations included:

- The upper floodplain (northern levee of Hunchee Lagoon) which was a high energy environment and a potential high resource area because of the size of the lagoon.
- The lower floodplain (north-western levee of Ral Ral Wide Water Lagoon on Reny Island) which was 2 m lower in elevation than the Hunchee lagoon location, was a lower energy environment and also in a potentially high resource area.
- The northern and southern levees of Thookle Billabong on Hunchee Island which provided three mounds. The total number of mounds in this area (n = 14) (Figure 6.1c) also suggested a high level of resources in the vicinity.

Diverse mound morphologies and the presence of nearby sand sheets ideal for occupation space (as demonstrated by survey and observation of extensive scatters of archaeological material and evidence of hearths) were also considered (Jones 2016; Jones et al. 2017; Westell et al. 2020; Craig Westell pers. comm. 2020, 2021; Westell 2022). The gradiometer study, in the vicinity of mound HIS_2_23, was conducted to prospect for subsurface combustion features near that mound and found no evidence of subsurface hearths in the area covered by the study (Figure 7.20).

8.4 The contribution of this study to understanding the archaeological record at Calperum

As noted at the beginning of this thesis, until recently there had been little archaeological research conducted about Aboriginal lifeways within the Riverland region of South Australia. This gap has been partly addressed through the initiation of a number of studies at Calperum Station undertaken by Flinders University since 2015. These were led by Professor Amy Roberts through a collaboration with RRMAC and which have added new knowledge about the deep Aboriginal connection to this landscape. These previous studies have included the analysis of stone, glass and shell artefacts (Incerti 2017; Thredgold 2016; Thredgold et al. 2017; Munt 2022; Roberts et al. 2020; Roberts et al. 2022), issues of contact and conflict (Burke et al. 2016; Roberts et al. 2017; Roberts et al. 2021), the correlation of geomorphology, archaeology and early occupation patterns (Dardengo 2019; Dardengo et al. 2019; Westell 2022: Westell et al. 2020) and the study of earth mounds (Jones et al. 2016; Jones et al. 2017; Jones et al. 2022; Ross 2019; Ross et al. 2019).

The primary purpose of the research reported here was to investigate local socio-economic processes associated with earth mounds at Calperum and to consider whether the results correlated with prior theories and concepts about Aboriginal socio-economic and cultural trends from the mid Holocene. A secondary purpose was to investigate whether the Calperum earth mounds contain evidence to support the purported broadening of Aboriginal diets, in that part of the MDB, during this same period. The research design was implemented through an integrated study of the contents and sediments of six mounds on the Calperum floodplain. To my knowledge, this thesis is the first to investigate these relationships and the first to use quantitative techniques to address this knowledge gap for mounds in the MDB (see Ó Foghlú 2021 for a similar study for mounds located in northern Australia. The key methods used included field survey, excavation, quantification and analysis of mound contents, including granulometry, loss on ignition, magnetic susceptibility, plant microfossil morphology, gradiometry, radiocarbon dating and element analysis using pXRF and ICP-MS.

This research aimed to establish a mound chronology, provide a range of landform locations and mound morphologies representative of the Calperum area and to allow sufficient scope to capture evidence of socio-economic changes through the use of the methods listed above. From these criteria, two eroded mounds (HCN20 and HCN21) were selected from the northern bank of the Hunchee Lagoon (upper floodplain) (Figures 6.1a and 6.4). A cluster of three mounds from the Double Thookle Billabong on the southern (lower) floodplain were selected to include a mound partly overlain with non-anthropogenic sediments possibly indicating greater antiquity (HIS_2_21). A further two mounds (HIS_2_22, HIS_2_23) retained ashy surfaces reflecting relatively recent use. In addition, one further mound (RRWWS3), which was adjacent to the Ral Ral Wide Water located on the southwest end of Reny Island, was selected as it retained an ashy surface appearance despite being eroded which was different to the other mounds selected. The location of all excavated mounds are shown in Figure 6.4. Dating of shell and charcoal samples associated with these mounds indicated ages encompassing the period from ~4807–4442 cal BP (WK52025) (4624 cal BP median age) up to the time of European invasion.

As noted in Chapter Seven, the mounds excavated for this study contained a number of potential anthropogenic components which were recovered by sieving in the field and were then bagged, sorted and quantified later in the Flinders University Archaeological Research Laboratory. These components included burnt clay nodules of varied size, charcoal fragments, a few stone artefacts, fragmented mussel shell, aquatic snail shell and small quantities of bone, all contained in a fine ashy sediment derived from the breakdown of burnt heat retainer clay. The close relationship to water features (Figure 6.1b), the presence of large quantities of clay heat retainer and charcoal, the minimal presence of lithic material within mound sediments and small amounts of bone, supported the hypothesis that the purpose of the Calperum floodplain mounds was unrelated to domestic occupation and living spaces but were used specifically for the intensive preparation of seasonally available *Typha* rhizomes.

8.5 Mounds at Calperum—interpretations relating to contents and function

8.5.1 Bone

As outlined above, all of the mounds excavated at Calperum have low numbers of stone artefacts and small amounts of faunal material present (other than shell derived from freshwater species of mussel and aquatic snails). Faunal remains other than shell constituted a small quantity (n = 19, wt. 14.5g) of bone fragments (rabbit, small rodent, small marsupial, fish and snake) and gastroliths from *C. destructor* (Table 7.3) (Appendix Five). Six indeterminate specimens of fish bone (37% of the total number) were recovered from levels 2, 3, 6 and 7 of mound HIS_2_23 (n = 6) and a single indeterminate specimen from level 1 of mound HCN21. Rabbit (*O. cuniculus)* bone constituted 6 of the 19 (32%) specimens of the faunal material recovered. A total of five specimens of O. *cuniculus* bone were found in levels 1, 2 and 3 of the older mound HIS_2_21 for which surface bioturbation by rabbit activity was clearly evident as surface burrows. An additional specimen was found at level 5 in mound HIS_2_23 where bioturbation (a burrow profile) was evident in the north-western corner of the excavation over levels 5–8 (Figure 7.7F). The remaining 30% of bone elements were indeterminate mammalian and snake specimens including a medium sized *Macropodia* vertebrae from level 1 of mound HIS_2_22, a fragment of a small mammal pelvis and a parietal fragment from levels 3 and 7 of mound HIS_2_23 respectively. Two vertebra from non-venomous and venomous species of snake were obtained from levels 4 and 1 of mounds HIS_2_23 and HCN21 respectively. The only specimen identified to species level was a left dentary of *Pseudomys bolami* (Bollam's mouse) found in level 2 of mound HIS_2_23.

The low incidence of bone in the earth mounds excavated at Calperum contrasts with the high quantities found in excavations of rock shelters and other living spaces in the lower Murray region of South Australia (see Wilson et al. 2022:200–214).

The relatively high presence of rabbit bone indicates bioturbation of mounds HIS_2_21 and HIS_2_23 by rabbits during the time following the introduction of wild members of this species by the Victorian landholder, Thomas Austin, in December 1859 (Fenner 2010:104). The low presence, in the Calperum mounds, of small native mammals, snake and fish bone and gastroliths from the common yabby (*C. destructor)* indicates the Aboriginal people who used earth ovens in these locations exploited small mammals, fish, reptiles and crustations in their vicinity when the opportunity was available. However, the low number found in these mounds suggests that they were infrequently cooked in these ovens. The main activity in these locations presumably was the cooking of other resources, e. g., *Typha* rhizomes (see 8.5.3 below) as previously noted in other regional locations in the MDB from archaeological and ethno-historical evidence (Martin 2006, 2011; Beveridge 1889:32–34; Eyre 1845 2:289–291, 254; Kirby 1895:27–28; Mitchell 1839 2:53, 60, 80–81, 134).

8.5.2 Freshwater mussel shell

Westell et al. (2020:166–168) demonstrated the antiquity and ubiquity of river mussel exploitation in the South Australian Riverland through a radiocarbon dating program (n = 31) conducted on shell middens located across both the Pike River area and the Calperum floodplains (Figure 6.1a). Their study indicated that the exploitation of freshwater mussel as a food source in the Riverland region, had begun by at least 30,000 cal BP, with an abrupt expansion of middens around 15,000 cal BP and again in the last millennia. This long history of resource use is evident in extensive shell midden deposits, including on the Calperum floodplain where the oldest mussel shell age obtained from a midden was 9460–9144 cal BP (Westell 2022). The general paucity and fragmented nature of mussel shell within the Calperum mound sediments (Table 7.2A–F), other than mounds HCN20 and HCN21 as discussed below in section 8.5.5, provides a striking contrast, and suggests that mussel shell found in most earth mound deposits is the product of a low level of casual consumption, transference along with aquatic plant roots and/or possibly resulting from the use of shell as tools. Tools made by Aboriginal peoples from mussel shell have been reported ethnographically in the MDB (e. g., Berndt and Berndt 1993; Eyre 1845; Taplin, 1879) and in the archaeological record (Mulvaney 1960, 1961; Roberts et al. 2021; Weston et al. 2017:229, 236). Angas (1847 vol. 1:55) observed the consumption of mussels, as well as their use for the processing of bulrush-root fibre and other purposes.

> The fresh-water mussels found in the muddy flats of the river are much sought after by the natives, who cook them by burying them in the ashes of their wooden fires. The shells are used to scrape the fibres of the bulrush-root, after it has been well chewed, for the purpose of making cord for their mats and baskets.

and:

> The sharp edge of the mussel-shell is used as a knife, and the women crop their hair by this means…Another shell, found in the reeds, serves the purpose of a spoon (Angas vol. 1:92).

The ethno-historical association of mussel shell with the processing of 'bulrush root' suggests that this is a potential explanation for some of the mussel shells found in the Calperum mounds and indicates an opportunity for future research through the analysis of edge use-wear on intact specimens.

8.5.3 Other fauna

The distribution of 38 specimens of freshwater snail taxa from the families Planorbidae and Thiaridae (including the genera *Isidorella, Gyraulus* and *Plotiopsis* spp.) through all mounds excavated provide proxy evidence for the transfer of aquatic plant roots for cooking in earth ovens within the mound features (Appendix Five). As outlined in Chapter Seven, such taxa are found in association with aquatic plants in ponds, billabongs, swamps and slow moving streams in the MDB (Ponder et al. 2020; Smith 1992; Smith and Kershaw 1979:76–89, 57–58; Walker 1988). This association is further confirmed by the presence of five intact single valves of the freshwater (lacustrine) mussel *V. ambiguus* which were very small and possibly transferred in mud along with rhizomes into mounds (one in HIS_2_23 L5, two in each of levels 1 and 3 of HCN21) rather than resulting from deliberate predation (Appendix Five). Alternatively, the two small single valves from level 3 of mound HCN21 may be associated with the shell lens established prior to mound formation.

These transfers would have occurred after harvesting of plant rhizomes from adjacent billabong and creek environments and prior to cooking in mounds established in close proximity to emergent macrophyte habitat. Given the relative absence of other faunal remains and occupational debris, this association provides circumstantial evidence of the relationship of mounds to aquatic plant resources such as *Typha* at Calperum, and is the preferred explanation for mound formation in conjunction with the discussion which follows.

8.5.4 Stone Artefacts

Artefacts recovered during excavation constituted a small number (n = 10, total wt. 26.7 gm) of chert and silcrete fragments (Appendix Six). Artefacts were also recorded during a survey of the immediate surroundings of mounds HIS_2_21, HIS_2_22 and HIS_2_23 (Appendix

Eight). This survey recorded 101 stone artefacts including chert (n = 48), silcrete (n = 5), sandstone (n = 12), crystal quartz (n = 1), glass (n = 14) and quartzite (n = 22). The analysis of artefacts found within mounds and the survey of surface artefacts found in the immediate surroundings of mounds HIS_2_21, HIS_2_22 and HIS_2_23, outlined in Appendix Six and Eight, were in alignment with the conclusions of Thredgold (2016:140) who stated that:

> Flakes were generally knapped without the use of complex knapping strategies, except to maximise the use of good quality raw materials, leaving behind an assemblage that indicates food processing activities being undertaken in the vicinity of the mounds.

And also concluded from the low numbers of stone artefacts present, that:

> …the Riverland earth mounds were single activity sites related to food and fibre processing and were not formed as a result of or used for occupation…

The surface artefact characteristics and distribution recorded was also in alignment with observations by Klaver (1998:278) of artefact scatters around mounds at Cooey Point, in the Murrumbidgee region, who noted ‘a deflated accumulation of materials’ with no defined patterning.

8.5.5 Heat retainer, mussel shell and charcoal concentration profiles

The relatively regular distribution of heat retainer material in the lower floodplain mounds HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3 as outlined in Tables 7.2C to F, and the stratigraphic diagrams in Figure 7.7C to F indicate that this material is present in all levels of these mounds. In contrast (Tables 7.2A and B, Figure 7.7A and B), heat retainer material reduces below level 4 in both HCN20 and HCN21 and is subsequently absent below level 6 in the latter. In both of these mounds, the decrease in heat retainer was matched by an increase in unheated sediment nodules penetrated by tunnelling which indicated bioturbation by ants (Stephen Hasiotis pers. comm. 2021). Fewer heat retainer nodules with depth is an indicator that the surfaces of these two mounds were heavily eroded, leaving only 20 cm of the underlying mound material (overwhelmingly made up of heat retainer material) over a transitional zone, containing a relatively intact concentration of mussel shell of varying fragment size, some heat retainer and bio-disturbed sediment, which extended to a hard clay layer, representing the original river levee, at the bottom of the excavations (Tables 7.2A, B, Figure 7.7A, B).

Mounds HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3 demonstrated a gradual reduction in the concentration of mussel shell and charcoal fragments with depth (Tables 7.2C to F). In contrast, mounds HCN20 and HCN21 contain a concentration of mussel shell at levels 3–4 which, during excavation, presented as shell lenses (Figure 7.7A, B) underlying the base of the original mounds. Consequently, the establishment of mounds HCN20 and HCN21 resulted in the penetration of these shell lenses by digging of earth ovens leading to the dispersal of some shell into lower strata. This is more pronounced in mound HCN20 than HCN21 (Tables 7.2A and B).

The results from artefact studies, the analysis of mound contents and the close spatial association of mounds to water features at Calperum align with ethno-historical information. This relates the formation and primary function of earth mounds in the MDB to the exploitation of *Typha* spp. rhizomes as a source of carbohydrate and fibre rather than as general living spaces (Beveridge 1889:32–34; Eyre 1845 2:289–291, 254; Kirby 1895:27–28; Mitchell 1839 2:53, 60, 80–81, 134).

8.5.6 Sediment analysis

8.5.6.1 Grain size, MS and LOI

A comparison of grain size plots (Figures 7.12, 7.13 and 7.14) of the Hunchee floodplain and mound sediments indicate coarser grain size fractions within the non-anthropologically modified auger floodplain sample (Figure 7.13) than the mounds (Figures 7.12 and 7.14) over comparable depth and age levels (0–45 cm, levels 1–9 respectively). The six mounds all exhibit a high level of sediment homogeneity (though not in respect of larger nodules of clay heat retainer, shell or charcoal) as a consequence of human bioturbation. Grain size, MS and LOI plots (Figure 7.14) reveal Aboriginal agency as the principal mound development process. This likely included digging and raking, the setting of new fires, the regular introduction of fresh clay (as heat retainer) and the reuse of mound sediments for capping prior to cooking (see Ó Foghlú 2021:362–397 for an ethnographic account of mound use in northern Australia). The MS plots of mound sediments show a higher low frequency MS signal than the floodplain sediments except for mound HIS_2_21. This is likely related to its older age, early abandonment and later bioturbation (homogenisation) by ants and rabbits. MS and LOI readings in mound sediments generally reduce with depth which is potentially related to the region of intensive burning shifting higher over time as the mound grows in height and lower levels become less disturbed. Such a process would include the continual addition of river clay as heat retainer, the addition of wood for fuel and leaching of lower mound levels by ground water which rose during periods of flooding. Leaching would have been more intense after ~2500 cal BP as variable ENSO related weather patterns ameliorated, and water availability increased (Gell et al. 2005). The impact of climate variability is discussed further below in section 8.6.2.

Mound RRWWS3 contained a sandy layer, noted during excavation, at the base of level 4 extending into level 5 (Figure 7.7C). Both RRWWS3 and HIS_2_22 indicate a dominance of medium sized sand grains and a reduction in organic content prior to level 4 (at c. 450 cal BP) (Figures 7.14D and 7.14F), which was not observed in the older (abandoned) mound HIS_2_21 and the younger HIS_2_23 (Figure 7.14C and 7.14E), which may reflect a discrete period of increased depositional energy related to a flood event at about 450 cal BP associated with the lower floodplain lying south of the Ral Ral/Hunchee anabranch creek system (Figure 6.1a).

While acknowledging a degree of homogenisation is present in mound sediments, the stratigraphic profiles and results of the analyses conducted are interpreted as evidence of decreasing post-depositional disturbance with depth, over the periods of active use. Clearly, low frequency MS and LOI results in mound sediments (other than HIS_2_21, which the sediment analyses and radiocarbon results demonstrate is extensively disturbed) are not uniform, as found in floodplain sediments not associated with mounds (Figure 7.13). Grainsize variations appear to reflect both anthropogenic and environmental influences. However, the sediment analyses must be interpreted carefully when considering changes in depositional conditions or to provide an accurate proxy for palaeo-burning intensity over time. Human agency, such as digging, fire making, clay heat retainer addition and raking in the mounds, is clearly the major agent of bioturbation. The difference in grainsize profile between the two closely situated and contemporaneous mounds HIS_2_22 and HIS_2_23 and the similarity between HIS_2_22 and RRWWS3 potentially demonstrate the environmental nuances which exist in these landscapes, as discussed further below. Similarly, the grainsize, MS and LOI profiles obtained for HCN20 and HCN21, together with discrete shell lenses found at levels 4 to 6 and 3 to 4 respectively, suggest Aboriginal agency of some complexity (Figures 7.12 and 7.14).

The sediment analysis results for mounds HCN20 and HCN21 indicate an increase in finer grain size fractions, a reduction in low frequency MS and a reduction in organic content below level 2 for both mounds, for which a reduction in heat retainer presence was also noted (see above) in addition to reduced sediment mixing (Figures 7.12 and 7.14, Tables 7.2A and 7.2B). The stratigraphy identified for mound HCN20 included a zone of soft/friable clay/sand from levels 2 to 6 which contained decreasing amounts of heat retainer nodules with depth and increasing quantities of bioturbation nodules from level 4 (Figure 7.7A, Table 7.2A). Similarly, HCN21 showed soft/friable clay/sand from levels 2 to 6 and an additional zone of grey silty/fine clay from levels 6 to 9 over a layer of coarser clay with decreasing amounts of heat retainer nodules from level 2 and increasing quantities of bioturbation material from level 4. (Figure 7.7B, Table 7.2B).

An increase in carbonate at level 3 in HCN20 is probably related to the shell lens found at this depth. The concentration of mussel shell in both HCN20 and HCN21 at levels 4 to 6 and 3 to 4 respectively, is in contrast to the nature of the dispersion of mussel shell found in the other excavated mounds. In the latter, shell is typically mixed more evenly through the deposit and is more highly fragmented. The results of the sediment analyses for HCN20 and HCN21 indicate a distinct change in sediment characteristics (with a predominance of silt and clay, and very fine sand fractions) at and below levels 2 and 3 respectively (Figures 7.14A and 7.14B). As is also indicated by the variation in heat retainer concentration with depth, this change confirms the top of a transitional zone (as shown by the dotted lines in Figure 7.14A and 7.14B) which extends to the base of the excavation. The lower extent of this transitional zone is marked by a reversal in heat retainer and bioturbation material content at levels 5 and 6 of HCN20 and HCN21 respectively (Tables 7.2A and 7.2B). This is also apparent in the trends of P and Ca concentration in Tables 7.8a and 7.12a. These observations are explored further below (section 8.7.4) in conjunction with a high resolution radiocarbon study of the lower levels of both HCN20 and HCN21.

8.5.6.2 Elemental concentration, pH and sediment colour

The concentrations of P and Ca (Table 7.8a, 7.12a, b) for mound HIS_2_21 correlate with the grain size, MS and LOI observations discussed above. This observation is also consistent with the bioturbation noted in this mound. All other mounds demonstrate a relative decline in both P and Ca with depth, indicating a tapered anthropogenic signature as the burning zone within the mounds was raised by ongoing use and the continuing addition of fuel and plant material at the working surface. The more pronounced relative decline in P and Ca concentration noted from level 4 for mounds HCN20 and HCN21 is comparable with trends obtained for heat retainer, sediment size, MS and LOI and is in accordance with the issues outlined above regarding the possible erosion of the top portions of these mounds and the intrusion of mound formation activities into underlying sediments when first established. Mounds HIS_2_22 and RRWWS3 show high levels of Cl and Na reducing with depth and are the only mounds with such a profile, reinforcing the conclusion that a flooding event associated with a pulse of saline ground water impacted both of these mounds.

HIS_2_21 and HIS_2_23 show much lower Cl and Na concentration profiles which also decrease with depth. HCN20 and HCN21 have relatively lower levels of Cl and Na suggesting a lower uptake of saline ground water potentially reflecting their higher (~ 2 m) elevation than the lower floodplain mounds (Table 7.1). The high concentration of Cl and Na in mounds HIS_2_22 and RRWWS3, in contrast to the other mounds, is of note and provides evidence of the environmental and ecological variability which prevailed within the Calperum floodplain in the past.

Tables 7.8a and 7.12a provide the Ba profile for all mound excavation levels at Calperum, lower values were demonstrated for HIS_2_22 and RRWWS3 at levels 4/5 (pXRF values of 58 ppm and zero and ICP-MS values of 148 and 128 respectively. The coincidence of lower pXRF and ICP-MS Ba signatures at levels 4/5 for both HIS_2_22 and RRWWS3is potentially linked to the flooding event postulated previously (however the greater confidence associated with of the ICP-MS results suggests a weaker correlation). Ba found in the sediments of river floodplain environments originates in the geological bedrock which underlies the water catchments and the plains through which rivers pass (Dalai et al. 2002; Wolgemuth and Broecker 1970:375). Potentially Ba is transported by clays derived from upstream sources and deposited during periods of low energy when finer grained material is deposited. Consequently, lower readings for HIS_2_22 and RRWWS3 for Ba are possibly related to periods of high energy and the deposition of a sand layer with a lower concentration at level 4 of both HIS_2_22 and RRWWS3 (although the relationship is weaker for the ICP-MS results).

The comparison of the pXRF and ICP-MS techniques used in this study indicated the limitations of the former method. However, pXRF does have advantages of portability, lower cost and convenience. In practice, pXRF can be useful in the early identification of trends in the data but it is recommended that a more accurate method such as ICP-MS be used for confirmation.

The pH profiles (Table 7.10) with depth for mounds HIS_2_22 and RRWWS3 show a reduction with depth from 8.0 to 7.7 and 7.7 to 6.5 respectively, all other mounds show higher alkaline profiles within in the pH range 9.6 to 7.5. Again, these readings support the hypothesis previously detailed in relation to the discussion above (see also section 7.2.6), regarding a possible flooding event across the Calperum floodplain about 450 cal BP. The pH results for mound sediments at Calperum have some correlation with the results of a previous study by Sullivan (1980:50) who found smaller mounds to have pH profiles between 5 and 6 and larger mounds between 8 and 9. However, the results reported here suggest the primacy of post depositional processes such as a significant flooding event and potential leaching (as demonstrated for mounds RRWWS3 and HIS_2_22) as an explanation for the differences observed between some mounds. This is the opposite conclusion to that advanced by Sullivan (1980:50) who favoured use and developmental processes as the operative factors.

The colour results shown in Table 7.10 for mound HIS_2_21 indicates a slight change from darker to lighter coloured sediment with depth. Mounds HIS_2_22 and HIS_2_23 both show uniform colour over the depth of each excavation, with the former slightly darker than the latter. RRWWS3 is uniformly very dark gray with a change to black in levels 7 and 8. In this instance the black colour is likely associated with the presence of a higher water table due to the close proximity of the Ral Ral Water Lagoon and the low elevation of the mound (18.2 m AHD).

Both HIS_2_22 and RRWWS3 show darker sediment colour than the other two lower floodplain mounds, potentially reinforcing their environmental association outlined above. Mounds HCN20 and HCN21 show darker sediment at levels 1/2 and 2 through 4 respectively, indicating a change in sediment characteristics at these levels which correlates to changes in sediment particle size.

Table 8.1: Plant microfossil (pollen) indication of dominant vegetation and climate at Calperum during the operational periods of excavated mounds. Ages listed were all from shell and located within the same or closest spit to the depth from which microfossil samples were taken.

Site	Level	Level cm	Mound age ranges from closest association cal BP	Location	Dominant vegetation (Percentage of pollen present)	Comment	Climate indicated
HIS_2_21	3	11–15	L3 3981–3723 L4 2429–2150	Thookle Billabong – lower (southern) floodplain	Amaranthaceae 50% Myrtaceae 25%	Low shrub dominant	Arid (lower precipitation/ water availability)
HIS_2_22	8	36–40	L8 523–335	Thookle Billabong – lower (southern) floodplain	Amaranthaceae 30% Myrtaceae 50%	Higher canopy dominant	Higher precipitation/water availability
HIS_2_23	4	16–20	L5 322–149	Thookle Billabong – lower (southern) floodplain	Amaranthaceae 20% Myrtaceae 45%	Higher canopy dominant	Higher precipitation/water availability
RRWWS3	3	11–15	L3 919–779	Ral Ral Wide Water – lower (western) floodplain	Amaranthaceae 35% Myrtaceae 30%	Both low shrub and high canopy	Transition
HCN20	4	16–20	L4 3700–3452 L4 3618–3396	Hunchee Lagoon – higher (northern) floodplain	Amaranthaceae 50% Myrtaceae 5%	Low shrub dominant	Arid (lower precipitation/ water availability)
HCN21	5	25–35	L3 2703–2354 L6 4404–4092	Hunchee Lagoon– higher (northern) floodplain	Amaranthaceae 60% Myrtaceae 10%	Low shrub dominant	Arid (lower precipitation water availability)

The elemental, pH and colour data indicates close correlation with the results obtained from the granulometry and content quantification analyses.

8.5.7 Plant microfossils and climate indications

Six sediment samples from excavated mounds in three wetland contexts in the Calperum floodplain (Figure 7.11, Table 7.7) were examined for pollen, phytolith and starch remains. Pollen and phytolith signatures for these contexts were sought to provide evidence of the locally dominant vegetation types, and consequently an indication of local climate conditions, at the time of operation of these mounds (Table 8.1). Starch residues were examined for possible evidence of the presence of geophytes and aquatic rhizomes within mound sediments.

Cyperaceae phytoliths and pollen were noted in two and four mound samples respectively. Collectively, evidence of Cyperaceae was recovered in five of the six samples examined (RRWWS3 was the outlier), suggesting local growth of sedges near mounds which indicates the presence of wetlands in close proximity during the operational periods of these mounds

(Cummins 2021). Cool season grasses were dominant, however both annual short and tall grasses also grew locally. Recovery of diatoms and sponge spicules indicate wetland habitats. Such wetland habitats typically provide both plant and animal resources for food, utensils, tools and fibre. Starch recovered in the pollen and/or phytolith studies could possibly indicate the use of USOs, aquatic rhizomes and seed processing from large-seeded grasses and possible baking through the use of mound heating elements. Alternatively, the presence of grass microfossils may simply be a non-anthropogenic environmental signature. However, none of the starches recovered were indicative of the processing of roots/tubers. The poor recovery and identification of ancient starch linked to the original use of Aboriginal earth ovens as reported in the Calperum mound study (Cummings and Varney 2021), confirmed work conducted at Fort Hood in Texas, by Laurence (2013) who found one fragment of starch out of 27 related to the past activities of Indigenous peoples. In addition to a lack of ancient starch in burnt rock mounds, the Lawrence (2013) study also found environmental contamination by modern starch in both field and laboratory contexts. Consequently, the poor preservation of ancient starchy residues and the strong possibility of modern starch contamination from agricultural and other sources in Australian Aboriginal earth mound environments suggests that these methods are unlikely to recover evidence of starch in studies of this nature (see also Martin 2006, 2011).

Pollen and phytolith evidence (Figures 7.18 and 7.19, see also Appendix Two) at Calperum included a number of plant species—including members of the fanflower family (Goodeniaceae, genus *Scarvola*), sunflower (Asteraceae), sedges (Cyperaceae), water milfoil family (Haloragaceae genus *Myriophyllum)*, grasses (Poaceae), nardoo (*Marsilea drummondi*) and bulrush (*Typha* spp.). Pollen results obtained from sediments from levels 3, 4 and 5 of the three mounds HIS_2_21, HCN20 and HCN21, indicated the dominance of Amaranthaceae (low shrubs), before an increase in Myrtaceae species (higher canopy trees) which dominate after ~1000 cal BP (Table 8.1, see also Cummins 2021 attached in Appendix two pp.303). The sediments from level 3 of HCN20 and level 4 HCN21 were located in close association with the shell lenses also found in these levels. Consequently, they are considered to be contemporary with these lenses. The intermediate age mound RRWWS3 (microfossil sample taken from level 3, 11–15 cm depth, where a shell sample at that depth was dated to 919–770 cal BP) demonstrated a mixed signature for both high and low canopy growth vegetation with a slight dominance by Amaranthaceae. The dominance low shrubby growth Amaranthaceae species indicate that arid conditions likely prevailed on the Calperum floodplain over the period 3700–3452 to 2703–2354 cal BP (Table 8.1).

The similarities in vegetation indicated by the pollen evidence suggests the sediment samples from mounds HIS_2_21 (level3), HCN20 (level 4) and HCN21 (level 5) share an earlier temporal context than do sediments for mounds HIS_2_22 (level 8), HIS_2_23 (level 4) and RRWWS3 (level 3) (Table 8.1). This is confirmed by the associated radiocarbon dates outlined in Table 8.1. However, as discussed, the dates for shell obtained from HCN20 and HCN21 show a likely (3 out of 4 samples) association with the shell lenses present in their stratigraphy and consequently do not necessarily have any relationship to the time of establishment of these two mounds.

When compared with chronological data from radiocarbon dating and climate research from the region, the relatively small number of samples (n = 6) analysed for plant microfossils have provided a useful insight into conditions on the Calperum floodplain. This will be further explored below in section 8.6.

8.6 Regional evidence of climate change and evidence from Calperum

8.6.1 Overview

The data from the Tareena Billabong (located at the eastern edge of the Chowilla floodplain—Figure 6.1a) paleolimnological study by Gell et al. (2005) indicated its formation at about 5000 cal BP during a period of relatively high rainfall and isolation from the main river channel (Gell et al. 2005:450). A climate transition to ENSO driven variable conditions in the Riverland region became active over the period ~3800–2500 cal BP (see also Bowler and Hamada 1971; Fitzsimmons 2013; Fitzsimmons and Barrows 2010; Gingele et al. 2004, 2007; Petherick et al. 2013:69–70; Shulmeister and Lees 1995). The billabong was reconnected to the main river after 3800 cal BP with the likely onset of ENSO related wet-dry cycles, episodic aridity and phases of elevated salinity (Gell et al. 2005:450). Improved conditions and higher water availability developed after 2500 cal BP. This improvement was indicated by low levels of Chenopodiaceae (subfamily of Amaranthaceae) pollen from ~2500 cal BP (Gell 2005:451). The microfossil results obtained from mounds at both the Hunchee Lagoon (HCN20 and HCN21), Thookle Billabong (HIS_2_21) and Ral Ral Wide Water (RRWWS3) at Calperum (Figure 7.11) for this study, while lower in resolution, show a transition in the vegetation present (Amaranthaceae to Myrtaceae) which indicates an amelioration of arid conditions prior to ~1000 cal BP (Table 8.1).

Bourman et al. (2022:609–611) argued that the presence of extensive freshwater mussel deposits in the lower Murray and Lakes region indicated that freshwater flows had been generally maintained along the main channel of the Murray River during the Holocene. However, other researchers have argued for some variability and overall reduced freshwater flows through the Murray River system. This was indicated by lower discharge into westward flowing rivers which resulted in a trend to more arid conditions within the MDB from ~5000 cal BP (Bowler and Hamada 1971; Fitzsimmons 2013; Fitzsimmons and Barrows 2010; Gingele et al., 2004, 2007; Petherick et al. 2013:69–70; Shulmeister and Lees 1995). The evidence from both microfossil analysis at Calperum and the paleolimnological study by Gell et al. (2005) at Tareena indicate lower water availability and variability between ~3800–2500 cal BP in the wide, anabranch floodplain systems in the Riverland region (see climate indications in Table 8.1). The analysis by Gell et al. (2005:451) indicates the onset of episodic periods of oligosaline to mesosaline conditions at Tareena during this period and which intensified between 3000 and 2500 cal BP indicating salinity levels likely reached levels above 5,000 ppm on a periodic basis (see also Gasse et al. 1987:5).

The evidence outlined above implies that flows in the main channel of the Murray River were likely to be insufficient to maintain previous levels of resource productivity on the Calperum floodplain for ~1300 years after 3800 cal BP. This would have reduced the availability of terrestrial animal and plant subsistence resources across the floodplain, and fish, crustations, water birds and mussels in the microenvironments associated with anabranch creeks, swamps, ephemeral lakes, billabongs and lagoons in these systems. The presence of an increased abundance of high-spine Asteraceae (e. g., flowering plants such as daisy and sunflower species) in level 4 of mound HCN20 is an anomaly which suggests higher moisture availability (Bement et al. 2007:46). Given the indications from the pollen of other genera present and the evidence from Tareena this is unlikely and is potentially a wind borne contaminant, or perhaps a result of the heterogeneity of floodplain conditions.

8.6.2 Climate change and the unusual circumstances of mounds HCN20 and HCN21

The anabranch fed system of water storage features (e. g., lakes, billabongs, swamps and lagoons) at Calperum would likely have been isolated from the main channel and subject to episodic periods of drought, elevated saline levels and disruption of various terrestrial and aquatic habitats after ~3800 cal BP (Gell et al. 2005). For instance, mussels are severely impacted by salinity levels above 3 g L^{-1} (3,000 ppm) (Walker et al. 2001) and their availability as a food resource reduced until the return of wetter and less variable conditions after 2500 cal BP (Gell et al. 2005). Given the likely impact of these ecological changes and the potential implications for mussel productivity in floodplain environments a potential change in procurement strategy on the Calperum floodplain is explored in conjunction with radiocarbon data in section 8.7 below.

Depending on the extent of water inundation and flow velocity, scouring of the levee and surrounding surfaces during periods of high energy and the deposition of silt during episodes of low energy would be expected. The surface of HCN20 is one metre higher than that of HCN21 which, together with scouring, may indicate differences in inundation intensity prior to mound formation and potentially explain the difference in grain size profile between levels 2 and 5, between the two mounds (Figure 7.7A, B). The upper layers were most likely removed by later erosion after formation exposing lower levels which show a coarser grained profile (Figures 7.12, 7.14A and 7.14B). The higher proportion of coarser grained material toward the bases of more intact mounds, supports this conclusion (Figure 7.14C–7.14F). The presence of relatively stable shell lenses at levels 3 and 6 of HCN20, and a higher percentage of coarser grains in the top excavation levels of this mound supports the interpretation that this mound was established much later than 3442–3231 cal BP which is the youngest age associated with shell from the lens found in the HCN20 excavation.

Figure 8.1 provides a current view of the current Hunchee Lagoon environment at Calperum. The Hunchee Lagoon was formed in a paleochannel of the Murray River sometime after about 8000 cal BP (Westell 2022:313), with the river gradually moving to its current location to the east as demonstrated by the point bar lateral accretion structures incised in Little Hunchee Island. A scour pattern can be seen at the northern edge of Little Hunchee Island indicating the direction of flow into Hunchee Lagoon during periods of high river levels and extensive flooding which probably influenced the stratigraphy of these mounds after their establishment, as discussed above. For instance, high periodic flows through the Hunchee Lagoon would have both erosional and depositional effects on surfaces of the levee both before and after the period of low water availability (~3800–2500 cal BP) posited above.

Figure 8.1: A view of the Hunchee Lagoon area showing the likely pattern during high river flow.

The survival of the shell lens in HCN20, the presence in level 6 of shell dated at 4404–4092 cal BP and a date for the hard clay surface at level 9 of the HCN21 excavation, at 4807–4442 cal BP suggests that scouring ceased or was reduced after this latter date then resumed after ~2500 cal BP. This is discussed further below in relation to younger ages obtained for both HCN20 and HCN21 which were likely initiated after 1000 cal BP, separating them from the earlier formation of the shell lenses.

8.6.3 Climate implications for the Calperum floodplain

The study at Tareena Billabong, indicated that it transitioned from a permanent water body to a seasonally (ENSO) activated lagoon subject to wet-dry and intermittent brackish conditions by ~3800 cal BP (Gell et al. 2005:450). The close proximity and similar geomorphic setting of the Calperum floodplain to the Tareena Billabong suggests the likelihood of similar conditions prevailing there at about the same time (locations shown in

Figure 6.1a). The plant microfossil analysis (Figures 7.18, 7.19 and Table 8.1) conducted for this study indicated the dominance of pollen from Amaranthaceae species in the sediment samples obtained from the mounds HIS_2_21, HCN20 and HCN21 at levels 3, 4 and 5 respectively. As previously discussed, the dominance of low level growth rather than high canopy trees indicates lower availability of water between ~3800 and ~2500 cal BP with a transition to higher water availability apparent at ~1000 cal BP (Table 8.1), which correlates with the evidence from Tareena (Gell et al.2005).

Reduced anabranch flows, wet-dry cycling and fluctuations in salinity levels associated with the onset of ENSO conditions, likely caused variable water conditions in wetland microenvironments located on wide floodplains located in the Riverland region, such as at Calperum, from ~3800 cal BP. Given episodic wet-dry conditions, variability in surface water flows and fluctuations in salinity levels (including in anabranch creeks, swamps, billabongs and lagoons), previously productive environments would likely suffer a decrease in subsistence resources, including terrestrial animals and some plants, as well as fish, crustations, waterbirds, shellfish and some aquatic plants (see Keen 2004:39).

The radiocarbon data collected from mussel shell for this study and that by Westell (2022) potentially allows the use of mussels as a proxy for a decline in food resources across the Calperum floodplain during the period 3800–2500 cal BP. *V. ambiguus,* otherwise known as the floodplain or billabong mussel due to its preference for these environments, is the most likely species found in floodplain environments at Calperum during periods of favourable water conditions (Jones 2011; Walker 1981; Westell 2022). With the onset of drying and brackish conditions both the riverine and lacustrine species of freshwater mussel found in the region would be adversely effected by drying and rising salinity (Walker 2017:33; Walker et al. 2001:18–19). Furthermore, the nature of the life cycle of both *V. ambiguus* and the river mussel *A. jacksonii* in the MDB indicates that numbers of these invertebrates would be seriously disrupted by repeated drying and low water conditions which impact fish stocks, since an early life cycle stage relies on the parasitisation of fish as a host (Walker 1981, 2017). A report by Sheldon et al. (2020:3, 36–43, 44–45) on the impact of dry conditions on mussel mortality during 2017–2019 in the northern MDB indicated mortality rates of up to 100 per cent during a two year drying event. Sheldon et al. (2020:45) indicated that recovery of mussel numbers in this instance was dependent on the survival of small populations in permanent water holes and further reliant 'on the recovery and movement of native fish populations' which require the return of sufficient river flow to allow successful spawning. An extended period of fluctuations in river flows over centuries, as potentially occurred after ~3800 cal BP, would have major adverse consequences for mussel habitats located in anabranch, lagoon and billabong environments. Recurring disruptions to floodplain recharging events and fluctuations in salinity levels would have adversely effected the continuous supply of aquatic resources as well as terrestrial animals and plants within the floodplain. Local Aboriginal people reliant on the availability of mussels and other aquatic resources (as discussed previously) in these locations would have of necessity sought alternative sources of nutrition.

Consequently, the loss or reduction in access to aquatic resources and an extended delay in habitat recovery potentially provided the impetus for a transition in subsistence procurement at Calperum as indicted by the establishment of mound HIS_2_21 at ~3800 cal BP. The formation of this mound indicates the addition of substantial quantities of aquatic plant rhizomes to diets through a new subsistence system based on the scaled up use of ground ovens and river clay as heat retainer material, with earth mounds surviving as the enduring landscape feature as evidence for these activities.

The shell lenses at two separated sites on the Hunchee Lagoon levee immediately below the two mounds HCN20 and HCN21 were dated to around 3723–3484 (WK52024) to 3442–3231 cal BP (OZAN56) and 2703–2354 (OZAN60) cal BP respectively. An additional age was obtained from a sample of shell from level 6 of HCN21 at 4404–4092 cal BP (OZAN62). These results indicated that mussel harvesting and consumption was a subsistence activity in this location prior to mound formation, and which was likely distributed along the length of the levee, indicating a mussel habitat of considerable extent. Also, the presence of mussel shell in level 6 of the HCN21 excavation, with an age range of 4404–4092 cal BP (OZAN62), indicates that the availability and consumption of mussels in this location occurred at this earlier time, and very likely before (Westell et al. 2020; see also Table 8.2 and Figure 8.2 for dates obtained from mussel shell found in mounds and middens at Calperum).

8.7 Interpretations from radiocarbon dating and plant microfossils

8.7.1 Overview

This research highlights the value of thorough landscape surveys and site selection, with due consideration given to geomorphological context and the potential chronology of individual wetland sites. The radiocarbon results obtained from mound contents for this study indicate that:

1. Mound sediments are very mixed so ages from both shell and charcoal are unlikely to be in stratigraphic sequence and dates are often inverted;
2. Ages obtained from charcoal must be interpreted with caution due to the potential for younger roots to penetrate mound sediments and be burnt during firing events;
3. Multiple ages derived from fragmented mussel shell and charcoal found in earth mounds most likely provide an estimate for the period of use of individual mounds;
4. The presence of relatively stable shell lenses in some mounds (e. g., as in mounds HCN20 and HCN21) can provide insights into possible changes in subsistence focus and procurement strategies; and,
5. Plant microfossil results have provided a useful correlation with both radiocarbon dating and previous climate research but with some caveats such as the presence of likely windborne contaminants such as *Pinus* spp. and the presence of Rhizophoraceae species.

8.7.2 Mixing of Mounds sediments—HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3

The sample of age determinations presented in Figure 7.15 provides clear evidence of the span of operation of mounds (HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3) (3981–3723 cal BP to modern, Tables 7.4 and 7.5) on the lower floodplain at Calperum despite issues with the inversion of dates within individual mounds. The adjacent mounds HIS_2_22 and HIS_2_23 appear to be almost contemporaneous, whilst the later use of mound RRWWS3 overlaps with the oldest age for HIS_2_22 (Figures 7.15 and 7.16). The range of dates for mound HIS_2_21 is much older with age determinations of 1864–1729 cal BP (OZZ568), 2429–2150 cal BP (OZZ567) and 3981–3723 cal BP (OZZ566) (Table 7.4). The ages obtained for HIS_2_21 are inverted, suggesting a significant degree of internal mixing has occurred, as is also indicated by the sediment results discussed above. The ages for RRWWS3 also exhibit a degree of inversion, though the bottom two samples are in temporal order with respect to one another. Whilst the inversions in HIS_2_21 and RRWWS3 are problematic for interpreting the internal stratigraphy of these sites, they are still valuable in terms of bracketing the age range of earth mound use at these locations. The dates from HIS_2_22 and HIS_2_23 (with the exception of OZZ571 from near the base of HIS_2_22) have overlapping age ranges which are statistically indistinguishable, suggesting a discrete period of mound activity over a few hundred years in each of these sites (Figure 7.15, Table 7.4). Shell from HIS_2_21 supplied the oldest date (3981–3723 cal BP (OZZ566) (Table 7.4) for the mounds excavated at Calperum. Thus, potentially establishing the earliest evidence to date for the emergence of a subsistence system at Calperum based on the large scale cooking of *Typha* rhizomes.

8.7.3 The problem with charcoal

Multiple age determinations are required to provide an estimate of the period of time that a mound was operational and can include ages on both shell and charcoal. However, the close correlation of ages on charcoal and shell samples taken from the same level was demonstrated only once in this study. The ages obtained were 4418—4158 (OZAN63) and 4404–4092 (OZAN62), for samples of charcoal and shell respectively from level 6 of mound HCN21, which demonstrated a mean difference of 40 cal BP. In this case, level 6 of HCN21 was just below the limit of mound disturbance indicating limited mixing of sediment at that level (Table 7.2b). Younger intrusive root material burnt during mound operation still represents a relevant event in the period of operation of a mound. However, charcoal is less reliable in assessing the time of initiation of a mound. This is due to potential contamination with younger carbon which is not representative of earlier stages of operation (Gillespie 1998:180).

In contrast, the results obtained for ages on shell provide higher reliability for both assessing a potential period of operation and in providing a terminus post quem (TPQ) age for its origin. The evidence from mound HIS_2_21 demonstrates that shell is subject to bioturbation when fragmented but is not affected by the uncertainty which arises from the burning of younger intrusive root growth. In effect, the status of shell as a manuport can provide an indication of an age range of operation for an earth mound and also provide a

TPQ age of greater confidence for its formation despite considerable mixing of mound contents. For instance, under this premise mound HIS_2_21 has a TPQ age at 3981–3723 (OZZ566) which is the current evidence for its possible initiation. Similarly, HIS_2_22, HIS_2_23 and RRWWS3 have TPQ ages of 525–335 (OZZ571), 322–149 (OZZ573) and 960–805 (OZZ991) cal BP respectively. The age determinations for mounds HCN20 and HCN21 display greater complexity but under the premise above and the application of the simplest interpretation they have TPQs of 502–326 (OZAN59) and 922–770 (OZAN59) cal BP respectively. The former is based on a sample of charcoal and is considered less reliable as an indicator of mound formation due to potential contamination by younger root material (Gillespie 1998; Harrison and Frink 2000:6; see also Bird 2013:353–360 for an overview of radiocarbon methodology).

The intensive dating program for the Calperum mounds (n = 28, Tables 7.4 and 7.5) has demonstrated the extensive mixing and inversion of contents which has occurred during operation. This has included both charcoal and shell samples except when located in undisturbed sediments (e. g., HCN21 level 6, Table 7.5). Hence, this study indicates a higher level of confidence for age determinations obtained from shell rather than charcoal where available, in relation to the estimation of the time of mound initiation. Consequently, shell is recommended as the preferred method of dating these features (see Gillespie 1998:178 for a consideration of the reliability of shell dates from midden contexts due to the association with 'human transport'). Shell fragments are commonly found in mounds in small quantities (except for instances of unrelated mussel predation, e. g., mounds HCN20 and HCN21), however, they are very likely manuports associated with shell tool use or rare instances of mussel consumption and are useful for establishing a chronology of mound operation.

The majority of previously published age determinations for mounds in the MDB have been derived from charcoal (see Appendix Nine for a list of calibrated ages for Australian earth mounds)[9]. Consequently, all previously published chronologies for earth mounds which rely on single determinations made on charcoal must be treated with caution until validated by additional research.

[9] Obtained from the AustArch database and calibrated using OxCal online at: <https://c14.arch.ox.ac.uk/oxcal.html#program>

The critical review by Gillespie (1998:169–182) of charcoal derived dates at the Willandra Lakes identified several problems associated with older dates on charcoal. These included inadequate pre-treatment chemistry on 'multicomponent' samples, particularly for black sediments and burnt bone in which humic acid contamination is common (Gillespie 1998:180). In contrast, in earth mounds the problem lies with younger dates due to root growth as discussed above. This correlates to the other conclusion by Gillespie (1998:180) that:

> Other difficulties not related to the dating laboratories add significantly to the confusion, such as the incorrect stratigraphic assignments and dubious associations sometimes made between samples, landscape features and human events.

The mixed nature of earth mound sediments and the presence of younger root growth which has been burnt during cooking activity is analogous to the issue outlined in the quote above.

8.7.4 The complexity of Mounds HCN20 and HCN21

Mounds HCN20 and HCN21 contain shell lenses which date to a period considerably older than the mounds themselves (Tables 7.4 and 7.5). Dates obtained, other than for shell lens material, show inversion in other mounds at Calperum. The establishment of mound HCN20 'through' an existing lens of mussel shell prompts several conclusions. These are:

1. The predation of freshwater mussels occurred at this location during the period defined by the two shell age ranges of 3700–3452 and 3442–3231 cal BP prior to the establishment of the mound; and,
2. Radiocarbon ages establish that the mound was operational at least between ~500 cal BP and European invasion; however,
3. Since this latter age was obtained from charcoal it is possible that the mound was established before 500 cal BP.

Similarly, conclusions regarding mound HCN21 are:

1. The age range of 2703–2354 (OZAN60) cal BP obtained on a shell sample from a lens found at level 3 HCN21 level (Table 7.5) indicated mussel harvesting at the Hunchee Lagoon at that time;

2. Ages of 922–770 cal BP (OZAN59) for shell obtained from level 1 and 727–579 (OZAN61) cal BP and on charcoal from level 3 indicate that this mound was established at or before 922–770 cal BP and operated at least until 727–579 cal BP.

The close age ranges for three samples of shell derived from shell lenses at levels 4 and 6 of HCN20 (3618–3396 cal BP, OZAN54, 3700–3452 cal BP, WK52024 and 3442–3231 cal BP, OZAN56) and for level 3 of HCN21 (2703–2354 cal BP, OZAN60) demonstrate relative positional stability of shell lenses within both mounds HCN20 and HCN21. Such stability suggests a minimal amount of disturbance which potentially indicates minimal/episodic use of these mounds. The two older ages obtained at level 6 potentially provide a TPQ age for the formation of mound HCN21, however, the presence of the shell lens at levels 2/3 (Figure 7.7B) and the sediment profile at level 6 (Table 7.2B) confirms that they lie below the zone of operational disturbance of the mound and are unlikely to be associated its formation and operation. The two age estimates of 4807–4442 cal BP (WK52025) and 4803–4423 (OZAN64) for charcoal found in level 9 of the HCN21 excavation (below the lowest level of the zone of mound disturbance at level 5/6) does provide confidence that the dense layer of clay, which was evident in the excavation at level 9, represents the palaeo surface of the levee at that time.

8.7.5 Microfossils

The plant microfossil analysis indicated by the presence of *Typha* pollen in sediments from RRWWS3 and HIS_2_22 (Figure 7.18) established the presence of this genus in the environment at Calperum post ~1000 cal BP, which was indicated by an age obtained for mound RRWWS3. The presence of Cyperaceae pollen in sediments from mounds level 3 of HIS_2_21, level 8 of HIS_2_22, level 4 of HIS_2_23, level 4 of HCN20 and level 5 of HCN21 indicates the presence of sedges and a wetland environment capable of supporting aquatic plants. Table 8.1 shows the ages associated with these sediments, which together with shell dates from mounds HIS_2_21 and HCN20 indicate a healthy wetland environment along the Hunchee Lagoon and on Hunchee Island in the vicinity of Double Thookle Billabong prior to ~3800 cal BP (Figure 7.11a and b).

That a more conclusive pollen signal for *Typha* was not provided in earlier mound sediments is potentially due to preservation issues associated with the temperatures and repeated disturbances involved in earth ovens during operation (Savory 2020:13). Similarly, only a small signature for starch was identified in the Calperum samples (Cummings 2021). Lawrence (2013) also reported the difficulty of obtaining evidence of identifiable starch from internal oven (burnt rock) mound environments in Texas as mentioned previously.

8.7.6 Summary of radiocarbon dates, plant microfossil results and resource availability

The oldest age-range determination for a Calperum mound was obtained from mound HIS_2_21 at 3981–3723 cal BP (OZZ566) (Table 7.4, Table 8.2) which demonstrated a relatively early establishment for earth mounds in the South Australian Riverland region. This is the oldest earth mound date in the MDB apart from those obtained from the western Hay Plain cluster reported by Martin (2006). As outlined previously, the earliest earth mound radiocarbon age (c. 4800 cal BP, WK-4101) in the MDB was reported on charcoal by Martin (2006, 2011) from a western Hay Plain mound (Tchelery 1), located on an environmentally stable palaeo-lake lunette. An explanation for the early age profile and large dimensions of the Hay Plain mound possibly relates to its location on a stable lake lunette rather than in a high energy riverine environment subject to both depositional and erosional processes (Martin 2006; Jones et al. 2017). The establishment of the Tchelery 1 mound at c. 4800 cal BP correlates with a trend to aridity in the MDB after ~5000 cal BP (Fitzsimmons 2013:92; Petherick et al. 2013) suggesting that the potential emergence of local ecological stress on traditional subsistence resources may have been associated with its early development. The research at Calperum demonstrates that mounds approaching the antiquity of the western Hay Plain examples can be found in selected parts of riverine corridors where topographic settings support their preservation.

Three age ranges of the four dates obtained for shell in mound HCN20 form a cluster around the time period 3700–3231 cal BP (Level 4 [n = 2] and level 6 [n =1]) with an outlier at level 2 with a range of 296–32 cal BP (OZAN52). The temporal cluster of the three earlier ages are very likely associated with the shell lens located at level 3/4 and unrelated to the mounds which were formed later. The age range of this cluster, the older age range from shell at 4404–4092 cal BP (OZAN62) from level 6 of mound HCN21, the age for mound HIS_2_21 at 3981–3723 cal BP (OZZ566), midden dates at 4421–4184 cal BP (WK50690), 3702–3566 (WK-47549), 3720–3562 cal BP (OZX282) and 3680–3460 (OZZ003) provide credible evidence of mussel harvesting on the Calperum floodplain from ~4421–4184 cal BP until 3442–3231 cal BP (Table 8.2 and Figure 8.2). The absence of dating evidence after this period possibly indicates a hiatus in mussel exploitation due to adverse climate conditions until ~2703–2354 cal BP (OZAN60) which correlates to the evidence provided by Gell et al. (2005) (see also Westell 2022; Westell et al. 2020).

The lack of evidence for the presence of mussels in archaeological contexts (middens and mounds—Table 8.2 and Figure 8.2) at Calperum over the period 3321–2700 cal BP suggests ecological change and a probable reduction in floodplain productivity associated with climate change from ~3800 cal BP (Gell et al. 2005). This, plus the early establishment of mound HIS_2_21 at 3981–3723 cal BP is likely evidence for a transition in subsistence strategies on the Calperum floodplain. The likely beginning of a transition in ecological conditions involving low water levels and fluctuations in salinity levels, suggested above for floodplain environments at Calperum from ~3800 cal BP, would have progressively impacted mussel availability. This would have occurred at salinity levels above 3 g L^{-1} (3,000 ppm) (Walker et al. 2001). The growth of *Typha* would also be impacted but not as severely as mussel growth in the first instance since *Typha* species are moderately salt tolerant (Beare and Zedler 1987; Hocking 1981; McMillan 1959; Whigham et al. 1989; Zedler et al. 1990). The growth of *Typha* is reported to be impacted at salinities above 3000-5000 ppm but mortality occurs in the range 10,000-25,000 ppm (Glenn 1995:75). These salinity sensitivities suggest that mussel survival would be affected prior to that of *Typha.* Such a significant difference in susceptibility to salinity levels supports the hypothesis that a change in subsistence strategy occurred ~3800 cal BP as an adaptation to deteriorating conditions within the anabranch fed water features on the floodplain.

Under the above hypothesis based on the available evidence, *Typha* exploitation was likely initiated in wetland locations closer to the main river channel which were affected less by ecological change. This is potentially demonstrated by the location and early age of mound HIS_2_21 (Table 7.4 and Figures 6.1a and 8.5). The early establishment of this mound on the levee of Thookle Billabong is potentially significant because of the low elevation of the

Table 8.2: Radiocarbon age determinations for shell samples reported from midden and earth mound sites located on the Calperum floodplain from 5750 cal BP (Tables 7.4 and 7.5; Jones et al. 2022; Westell et al. 2020; Westell 2022:516–517).

Site ID	Laboratory code	Material sampled	Calibrated age (cal BP 95.4%)	Median age (cal BP 95.4%)
HIS_2_23	OZZ572	Shell	283–0	142
HIS_2_23	OZAB05	Shell	283–59	171
CAPR18_S36	OZZ011	Shell	284–145	215
HIS_2_22	OZZ570	Shell	295–0	148
HCN20_2_S	OZAN52	Shell	296–32	164
HIS_2_22	OZZ569	Shell	321–144	233
HIS_2_23	OZZ573	Shell	322–149	236
CAPR18_S24	OZY998	Shell	440–153	297
CAPRI17_19	OZX279	Shell	450–290	370
CAPR18_S02	OZZ009	Shell	497–327	412
CAPRI17_10	WK-52896	Shell	510–339	425
CAPRI17_22	WK-48702	Shell	518–475	493
CAPRI17_19	WK-47548	Shell	521–469	495
HIS_2_22	OZZ571	Shell	523–335	429
CAPR18_S41	WK-52893	Shell	524–492	508
CAPR18_S41	OZZ005	Shell	527–493	510
CAPR18_S41	WK-52891	Shell	531–496	514
CAPR18_S41	WK-52892	Shell	532–496	514
CAPR18_M03	OZZ004	Shell	532–496	514
CAPR18_S24	OZY999	Shell	534–493	514
CAPR18_S41	WK-50692	Shell	538–490	514
CAPRI17_05	OZX281	Shell	540–498	519
CAPRI17_23	WK-52028	Shell	543–507	525
CAPRI17_19	OZY996	Shell	547–504	526
CAPRI17_23	OZX286	Shell	622–517	570
CAPRI17_19	OZY997	Shell	649–545	597
CAPRI17_10	OZX276	Shell	651–552	602
CAPRI17_09	OZX277	Shell	723–571	647
CAPRI17_10	WK-47547	Shell	729–670	700
CAPRI17_14	OZZ008	Shell	770–680	725
CAPRI17_14	OZX283	Shell	897–722	810
CAPR18_S11	WK-50693	Shell	903–727	815
CAPRI17_14	WK-48701	Shell	904–738	821
CAPR18_S06	Wk-52026	Shell	906–774	840
CAPR18_S24	WK-52897	Shell	915–772	844
RRWWS3	OZZ992	Shell	919–770	845
HCN21_1_S	OZAN59	Shell	922–770	846
RRWWS3	OZZ991	Shell	960–805	883
CAPRI17_23	OZX285	Shell	960–806	883
CAPRI17_19	OZX280	Shell	1269–1074	1172
CAPRI17_19	WK-52900	Shell	1277–1177	1227
CAPRI17_19	WK-52899	Shell	1287–1177	1232
CAPRI17_10	OZY995	Shell	1295–1176	1236
CAPRI17_10	WK-48700	Shell	1299–1185	1242
HIS_2_21	OZZ568	Shell	1864–1729	1797
CAPR18_S06	OZZ000	Shell	2056–1921	1989
HIS_2_21	OZZ567	Shell	2429–2150	2290
HCN21_3_S	OZAN60	Shell	2703–2354	2529
HCN20_6_S	OZAN56	Shell	3442–3231	3337
HCN20_4_S	OZAN54	Shell	3618–3396	3507
CAPRI17_17	OZZ003	Shell	3680–3460	3570
HCN20_04	WK52024	Shell	3700–3452	3576

Table 8.2 Continued.

Site ID	Laboratory code	Material sampled	Calibrated age (cal BP 95.4%)	Median age (cal BP 95.4%)
CAPRI17_22	WK-47549	Shell	3702–3566	3634
HIS_2_21	OZZ566	Shell	3981–3723	3852
HCN21_6_S	OZAN62	Shell	4404–4092	4248
CAPRI17_14	WK-50690	Shell	4421–4184	4303
CAPR18_S36	OZZ010	Shell	5290–4976	5133
CAPR18_S37	OZZ001	Shell	5551–5312	5432
CAPR18_S25	OZZ002	Shell	5660–5478	5569
CAPR18_S37	WK-52895	Shell	5741–5596	5669
CAPR18_S37	WK-52894	Shell	5885–5602	5744
CAPRI17_14	WK-52027	Shell	5889–5656	5773
CAPRI17_19	WK-52898	Shell	5895–5606	5751
CAPRI17_14	WK-52351	Shell	5910–5660	5785

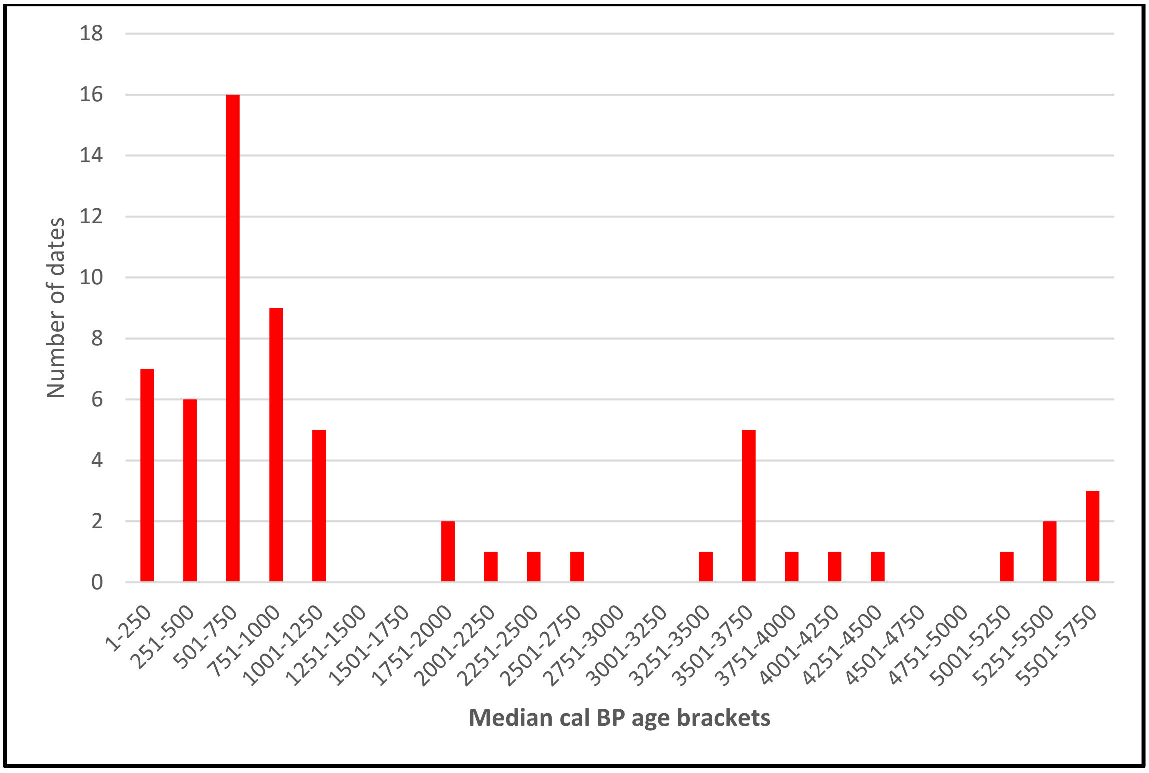


Figure 8.2: Combined plot of shell ages (calculated as a median of the calibrated range) in 249 year brackets for the period from 5750 cal BP, from midden and mound sites on the Calperum floodplain (Tables 7.4 and 7.5; see also Westell et al. 2020; Westell 2022:516–517).

lagoon bed (14.9 m AHD) and its direct link to the main river channel which indicates a higher likelihood of water flows or ground water availability during dry periods than were available to other parts of the floodplain, thereby maintaining *Typha* habitat and the opportunity to offset a decline in traditional food resources. Additional research would be beneficial to solidify these hypotheses. Distribution patterns of shell ages and potential scenarios for subsistence procurement in this context are considered in section 8.8.

8.8 The implications from climate change—mussel consumption and *Typha* exploitation on the floodplain at Calperum from ~3800 cal BP

8.8.1 Overview

Westell et al. (2020), Westell (2022), Jones et al. (2022) and this study reported 63 radiocarbon ages in total from mussel shell in earth mound and midden contexts on the Calperum floodplain (Table 8.2 and Figure 8.2). These ages cluster at 1250–0 cal BP (n = 43) (including 33 from middens and 10 from mounds), from 2750– 1751 cal BP (n = 5) and at 4500–3251 cal BP (n = 9), the latter including four ages from a midden context and five from earth mounds. These nine latter ages, includes the earliest age obtained from a Calperum mound site (HIS_2_21) as discussed above (see also Tables 7.4 and 7.5).

The pattern of dates reported by Westell et al. (2020) and Westell (2022) and the age ranges obtained in this study possibly indicate climatically induced fluctuations, and possible extended periods of disruption, in the supply of mussels (and other resources) in floodplain environments at Calperum. From the evidence discussed above this likely continued for about 800 years between ~3300 and 2500 cal BP, as also indicated by the Gell et al. (2005) study, and diminished the availability of mussels in anabranch, lake and billabong environments as a readily available staple food. The anabranch system is the main surface source of water for lakes and billabongs (and consequently floodplain mussel and other animal and plant habitats) on the Calperum floodplain. The period 3500–2251 cal BP demonstrates three shell ages (Figure 8.2). These samples were derived from earth mound contexts (from mound HIS_2_21 located close to the main river channel and two from each of the shell lenses located under mounds HCN20 and HCN21 at Hunchee Lagoon). The age range of 2703–2354 cal BP for a shell sample from a lens located at level 3 of mound HCN21 suggests that a potential amelioration of climate, a recovery of mussel habitat and a resumption of mussel predation occurred in the Hunchee Lagoon area after ~2500 cal BP.

Alternatively, the gap in mussel exploitation at Calperum may be due to taphonomic and/or sampling issues. However, given the number (n = 63) of shell dates obtained from two site types—middens and mounds, the ecological evidence from Tareena Billabong and the clustering pattern of shell dates shown in Figure 8.2, the hypothesis for a decline in mussel availability (and other resources) outlined above is argued to be reasonable until additional research and further age determinations of shell can be undertaken.

8.8.2 A potential scenario for subsistence change on the Calperum floodplain

Based on the evidence presented in section 8.7 mussel availability and consumption likely continued during the period ~3800 to ~1200 cal BP at Calperum but would have been concentrated on the banks of the main river channel where freshwater flows continued, albeit adversely influenced by variability and diminished discharge upstream (Bowler and Hamada 1971; Fitzsimmons 2013; Fitzsimmons and Barrows 2010; Gell et al. 2005; Gingele et al., 2004, 2007; Petherick et al. 2013:69–70; Shulmeister and Lees 1995). The presence of shell in the lower floodplain mound HIS_2_21 dating to 3981–3723, 2429–2150 and 1864–1729 cal BP, indicated a continuing presence of mussels in the southern part of Hunchee Island as well as the initiation and continuity of mound use in this location.

Under the scenario outlined above, a decline in water availability across the anabranch fed system of lakes, swamps and billabongs at Calperum would have led to a decline in both terrestrial and aquatic food resources across the floodplain. The lifeways of Aboriginal groups at Calperum would have contracted to areas close to the main river channel to access the resources of the associated environment. Continuing adverse climatic conditions and pressure on declining resources provided the impetus to adopt a food production system by taking advantage of a natural ecological niche involving *Typha*. This opportunity likely related to the proximity of the main river channel and a continuity of conditions suitable for the survival of *Typha* in the nearby Thookle Billabong. This finding correlates early *Typha* exploitation to the onset of the ENSO weather patterns identified by Gell et al. (2005), a continuing presence of mussels, other aquatic resources and the availability of *Typha* in the vicinity. The paucity of dates from mussel shell between ~3300 and ~2500 cal BP suggests declining returns from floodplain environments reliant on anabranch recharging. This induced a redirection of group and clan resources to the seasonal exploitation of *Typha* close to the main river channel. The return of wetter and less variable conditions from ~2500 cal BP indicated by palaeolimnological evidence (Gell et al. 2005), plant microfossil evidence (Figure 7.18) and the age range of ~2703–2354 cal BP (OZAN60) obtained for a shell sample at level 3 of mound HCN21, potentially indicates the return of conditions suitable for the expansive growth of both emergent macrophytes and prey habitat recovery across the floodplain from this time (albeit with fluctuations in water availability as potentially indicated by the lack of mussel dates during the period between 1750–1500 cal BP). Under this scenario, after the establishment of the new production system Aboriginal people on the Calperum floodplain would have progressively targeted new stands of *Typha* leading to the abundance of mound locations now demonstrated at Calperum. The increase in midden and mounds after ~ 1000 cal BP indicated by the dating evidence (Figures 7.15, 8.2 and Table 8.2) is potentially evidence of growth in the Aboriginal population at Calperum after this time. Alternatively, the higher presence of younger sites in an active floodplain environment may reflect taphonomic factors.

8.9 Section Summary

Given the early age of mound HIS_2_21 on the lower floodplain at 3981–3723 cal BP and the chronological data for shell on the Calperum floodplain, it is highly probable that heat retainer technology for the cooking of *Typha* roots was in use at Calperum by this time. A transition in subsistence strategy on the Calperum floodplain is indicated after ~3800 cal BP. The establishment of mound HIS_2_21 adjacent to a billabong located 200 m from the main river channel at ~3981–3723 cal BP closely correlates to climate change at this time (Gell et al. 2005). The early age range of 4404–4092 cal BP (OZAN62) for shell found at level 6 of the HCN21 excavation is ~400 years earlier than the establishment of mound HIS_2_21 which suggests prevailing environmental conditions at the time supported mussel harvesting and consequently available floodplain resources in general (Figures 6.1a and 8.4). As conditions deteriorated Aboriginal people likely responded to ecological change and the consequent reduction in resources in billabong, lagoon and anabranch locations due to low water availability and rising salinity in water features across the floodplain.

I argue that the transition in subsistence procurement on the Calperum floodplain outlined above, involved long-term fluctuations in the supply of traditional food resources and a consequent response which involved the establishment of a new food production system. This was enabled through the integration of a new or under-utilised seasonally abundant resource (*Typha* spp.), a logistical change of scale in the use of an existing technology (heat retainer cookery) and active resource management through the use of fire, digging and harvesting, as discussed by Gott (1999:42). The innovative repurposing (and rescaling) of heat retainer technology was the key for the seasonal exploitation of emergent macrophytes on the Calperum floodplain from ~3800 cal BP.

The initiation of mound HIS_2_21 at ~3800 cal BP likely followed a reduction in floodplain productivity and is evidence of a change in focus of local groups to areas adjacent to the main river channel where resources were still available. This would have led to a higher Aboriginal population density and greater pressure on depleted resources. The continuation of wet-dry cycles over an extended period, leading to long-term decreases in resource productivity, provided the impetus for innovation and the implementation of the food production system outlined.

Under this hypothesis, improvements over time in local ecological conditions would lead to the progressive establishment of mounds in different locations in the floodplain, demonstrating the persistence and value of this production system. In effect, Aboriginal people at Calperum broadened their diet via the addition of a new seasonal food production strategy to their subsistence repertoire, demonstrating cultural, technical and socio-economic innovation and the ability to reorganise people to address external challenges. However, further research into the ages of mussel shell middens and shell from earth mounds in this region is required to provide higher resolution and clarify these associations.

The research results discussed here have added to the information derived from ethno-historical sources to clarify the relationship between the use of aquatic plant foods, the role of earth mounds and the potential influence of ecological change caused by climate variability. Earth mound sediments have proven to be a useful source of information for the investigation of plant based subsistence at Calperum. Thirty-eight aquatic snail shell specimens normally associated with aquatic plant habitats in wetland environments, were found distributed through all mounds excavated. This provided circumstantial evidence for the transferral of mud and plant root material from nearby water features, constituting a useful proxy for the harvesting and movement of *Typha* rhizomes into mounds for cooking at Calperum. This evidence correlates to the archaeological evidence from the western Hay Plain (Martin 2006, 2011) and the ethnohistorical observations cited previously (Beveridge 1889:32–34; Eyre 1845 2:291, 269; Kenyon 1912:102; Kirby 1895; Mitchell 1839 2:53, 60, 80–81, 134). Beveridge (1889), Mitchell (1839), Kirby (1895) and Krefft (1865) provided first-hand accounts of the extensive use of *Typha* rhizomes by Aboriginal people within floodplain environments of the MDB which was interpreted, at the time, as a form of cultivation. The management of *Typha* as a form of domiculture (as described by Gott 1982:65) enhanced *Typha* habitat over time at Calperum, increased productivity and supported a transition in procurement through the novel supply of large quantities of carbohydrate and fibre on a seasonal basis. The transition involved a reorganisation of intra group labour resources and helped mitigate the effect of adverse environmental conditions associated with the onset of ENSO generated climate variability from the mid Holocene. The increased labour requirement in harvesting and preparing large quantities of *Typha* roots for cooking in oven mounds would have been a major change from traditional hunter-fishing-gathering activities. This would have required greater co-ordination of group members (based on existing family and clan relationships) and presumably a high level of leadership to achieve this goal. Indeed, ethno-historical accounts indicate a high level of organisation in the exploitation of *Typha* when first observed (Beveridge 1865, 1869, 1883, 1889; Eyre 1845; Kirby 1895; Mitchell 1838).

The quantification of mound contents including heat retainer and bioturbation material, bone, shell and stone artefacts provided evidence for mound formation processes and changes in subsistence systems related to mound development. Sediment grain size, MS, LOI and elemental analyses in conjunction with radiocarbon age determinations have clarified mound formation processes and enabled the identification of a likely transition in subsistence procurement systems and lifeways after ~3800 cal BP which then persisted on the Calperum floodplain until European invasion.

Twenty-eight age determinations on shell and charcoal obtained from earth mounds at Calperum have framed this narrative and allowed a correlation with climate research. The evidence indicates a relationship between the early development of mounds at Calperum to a widespread deterioration in climate patterns which developed in the Australian region from the mid Holocene (Bowler and Hamada 1971; Fitzsimmons 2013; Fitzsimmons and Barrows 2010; Gell et al. 2005; Gingele et al., 2004, 2007; Petherick et al. 2013:69–70; Shulmeister and Lees 1995). The research detailed here has demonstrated a near continuous chronology for the use of earth mounds on the Calperum floodplain from at least 3981–3723 cal BP until the time of European invasion. The early age obtained for shell samples found in the HIS_2_21 mound highlight the potential for the preservation of archaeological sites (including mounds) over the long term despite the inherently dynamic nature of floodplain environments (see also Westell et al. 2020). Ultimately, while preservation is an important factor in mound chronology it is important to consider the landscape in a detailed way when interpreting the chronological distribution of mounds in riverine settings.

Recent climate research, examined in relation to new knowledge about Aboriginal economic systems at Calperum, has added to the understanding of socio-economic practices at Calperum, and by extension, the wider riverine systems of the MDB. This has been achieved through an integrated approach focussing on content and sediment analyses, plant microfossils and radiocarbon dating associated with the intensive use of a common technology (heat retainer earth ovens). Evidence of ecological change has allowed the correlation of behavioural change to climatic variability although it is acknowledged that other factors are always at play within complex systems. The sampling of both anthropogenic and environmental trajectories has also provided evidence of behavioural change associated with the implementation of technical innovation by Aboriginal people and subsequent changes in socio-economic practices, associated with variable wetland environments at Calperum, from at least 3981–3723 cal BP.

Furthermore, the results confirm that mound formation along the western Murray River corridor began soon after the initial uptake of mound use in the MDB, providing further insights into a regional pattern of economic change in this region from the mid Holocene, specifically around the use of food resources derived from aquatic plants. The age results indicate a continuity of mound use at Calperum that suggests earth mounds were an important element of Aboriginal subsistence procurement systems in this part of the MDB from at least 3800 cal BP. Seasonal food production achieved through the management of a natural ecological niche, comprising emergent macrophytes in wetland environments, helped mitigate risk in an environment defined by variability.

The likely move to large scale seasonal exploitation of emergent macrophytes through the repurposing of an existing technology (heat retainer cookery) is an example of innovation by Aboriginal peoples in response to deteriorating environmental conditions. The results obtained from this study indicate an adaptive response to environmental change involving a socio-cultural reorganisation which was initiated within small groups. Under this hypothesis, this response likely entailed the development of new co-operative socio-economic and cultural systems, including potential changes in the economic role of women and a potential enhancement of their social status within local groups (see Martin [2006] for a detailed discussion on this aspect).

The analysis of ethno-historical accounts (with due consideration of potential observer biases) indicate that Aboriginal women managed, and operated processes associated with the preparation of plant foods in the past. Consequently, they were likely to have been associated with developments which led to the large scale harvesting of aquatic plant roots and the establishment and operation of earth mounds in the first instance (Beveridge 1889:32–34; Eyre 1845 2:291; Kenyon 1912:102; Mitchell 1839 2:53, 60, 80–81, 134). As discussed above, the inferred depletion of terrestrial and aquatic food resources (signalled by the decline in mussel availability) from the anabranch systems within the Calperum floodplain, from ~3800 cal BP, has been identified as the likely trigger for a change in subsistence procurement.

Isotopic evidence has indicated that mussels, crustations and fish were a significant food source in the past for women and juveniles within the MDB, while adult men had a higher level of meat in their diet (Pate 2006:232; Pate and Owen 2014). Consequently, a reduction in aquatic resources in floodplain environments suggests that a change in subsistence strategy was likely led and implemented by women. This would have encompassed the generation and adoption of new ideas including a change in the logistic scale of heat retainer cooking practices and an associated reorganisation of labour. This has provided insights into the flexibility of Aboriginal socio-cultural systems and the implementation of technical and social innovation within them.

The establishment of a new seasonal subsistence strategy based on a plentiful supply of raw material and a scalable process which was capable of producing large quantities of carbohydrate and fibre was a major reorientation away from traditional subsistence procurement based on fishing, hunting and gathering. The timely provision of large quantities of food during a period of adverse environmental conditions would have supported existing groups and allowed seasonal gatherings to continue and grow larger, which would have maintained wider socio-cultural interaction and allowed the spread of new ideas and practices, strategic alliances and opportunities for trade. Furthermore, the evidence outlined here can inform wider debates associated with technical and social adaptations to environmental change and socio-economic intensification in late Holocene Aboriginal societies.

8.10 A consideration of theory, innovation, BSD and the evidence from Calperum

8.10.1 Introduction

The study detailed in this thesis was focused on whether an integrated analysis of earth mound contents and sediments from Calperum could provide information which would contribute to a range of debates associated with the archaeological study of Australian Aboriginal societies. The strands of these debates are associated with interpretations of archaeological evidence which claim to indicate an acceleration in socio-economic activity and population growth during the mid-late Holocene. Arguments have been variously focussed on:

1. The validity of intensification in the first instance;
2. The scale of intensification of any acceleration that may have occurred;
3. The primacy of internal and external social factors as key drivers in such an intensification;
4. Climate variability as a relevant factor in behavioural change during this period;
5. A consideration of models of behavioural change which underpin socio-economic and cultural development within mid to late Holocene Aboriginal societies; and,
6. The potential broadening of diets in association with socio-economic acceleration.

As detailed in Chapter Four, a major debate related to the last 5000 years of Australian Aboriginal lifeways involves a purported continental level socio-economic intensification and an associated demographic trajectory of growth which was argued to have had its origin in the terminal Pleistocene (Lourandos 1983, 1997; Williams 2013; Williams et al. 2015a, 2015b). The analysis in this section considers whether evidence from earth mounds located in a floodplain context at Calperum supports such hypotheses. Another purpose of this section is to consider whether the socio-economic and cultural significance of earth mounds is an indicator of innovation in Aboriginal lifeways at Calperum and in the wider region. Thirdly, the evidence from Calperum will be considered in relation to a broadening of Aboriginal diets from 5000 cal BP which has been argued to have been related to socio-economic intensification over this time (Edwards and O'Connell 1995; Haberle and David 2004). Williams et al. 2015b:1, 9–12) also argue for socio-economic intensification during this period but provide a nuanced and more complex scenario which includes the influence of adverse environmental conditions, broadening of diet and the abandonment of some marginal areas.

8.10.2 Socio-economic intensification, climate and social processes in Australia

8.10.2.1 Background: The grand intensification narrative—a hierarchical top down perspective

The concept of a continental level socio-economic intensification in Australian Aboriginal societies during the Holocene, was originally conceived by Harry Lourandos (1983, 1985, 1997). Lourandos (1983, 1985, 1997) adopted a neo-Marxist perspective in arguing that socio-cultural change associated with hierarchical power relationships influenced economic behaviour and were instrumental in an intensification of socio-economic activity and demographic growth that he identified in the Australian archaeological record during the late Holocene. Internal and external social factors were deemed to be the key initiating influences, rather than the primacy that previous researchers had assigned to climate change (Lourandos 1983,1997:334–345; McNiven 2006:95; see also Bowler and Hamada 1971; Fitzsimmons 2013; Fitzsimmons and Barrows 2010; Gingele et al., 2004, 2007; Petherick et al. 2013:69–70; Shulmeister and Lees 1995). Brian (2006:112) summarised the role of Harry Lourandos in initiating and driving a neo-Marxist influenced social theory:

> …which privileged social and political forces over other potential determinants of human behaviour such as natural environmental productivity or purely economic motivations.

[and which were]:

> …a radical departure from what Lourandos has called the 'traditional approaches then prevalent in Australia…the uneasy combination of traditional culture history, cultural ecology and New Archaeology 'processualism'…heavily laced with environmental determinism (Lourandos 1984:29, 1997:xvi, 2, 308–309).

Williams et al. (2015b) used a SPD analysis of radiocarbon dates which they argued provided evidence for with a late Holocene socio-cultural and economic intensification and an associated high rate of growth in population which accelerated in the last 1000 years. They also correlated changes in socio-economic behaviour with episodes of climate variability (Williams et al. 2015b; see also Turney and Hobbs 2006 and Tibby et al. 2006). Williams et al. (2015b:8) used SPD data to argue for a late Holocene socio-economic and cultural intensification at a continental level suggesting that, from the period of the MHCO at about 7000–6000 cal BP, there was a:

> …reduced exploitation of the landscape [which was] associated with increasing populations…[and] growing numbers of archaeological sites may/likely reflect saturation of habitats, resulting in increasing distance between productive patches, and leading to greater consideration by hunter-gatherers of becoming more sedentary, broadening their diet and/or increasing their technological investment in resource procurement.

[And given these]:

> …changes in land-use occur at the end of a 3,000 year period of climatic stability, and importantly before the onset of ENSO aridification at ~4ka, they are likely a result of internal social, economic and/or demographic change. It appears that when resources were prolific, there was greater opportunity for the initiation of low-level food production in tandem with hunter-gatherer activities. (Low-level food production is a term given to societies that fall within the middle ground between hunter-gatherers and agriculturists, having elements of both, but not easily assigned to either. Here, we consider low-level food production to reflect hunter-gatherers that have initiated some elements of domestication).

The continental intensification model as originally proposed by Harry Lourandos, and supported by others, relied on an interpretation of the archaeological record which posited inter and intra group societal factors as the main drivers for an observed socio-economic intensification during this period (Beaton 1977, 1985; Bowdler 1981; Lourandos 1983, 1985, 1997; Lourandos and Ross 1994:54–55; Ross 1985; Ross et al. 1992; Williams 1987). In support of this hypothesis, Lourandos (1997) argued for an increase in the 'complexity' of Aboriginal social networks associated with an increasing rate of population growth from the mid Holocene. Similarly, Ross et al. (1992:107) discounted the influence of climate on mid Holocene Aboriginal societies, in contrast to behavioural changes during the LGM. They consequently argued that social factors were an increasingly dominant influence on landscape use and adaptation from that time.

In contrast, Williams et al. (2015b) considered that population growth was mediated by adverse climate variability after the onset of ENSO conditions over the period 4500–2000 cal

BP. After 2000 cal BP they argued that a climate amelioration allowed for an intensification of ‘mobility strategies and technical innovations that had been previously developed in the mid Holocene which culminated in “the complex and religious societies”’ reported by early observers at the time of first contact (Williams et al. 2015b:12).

Debates about socio-economic intensification modelling in Australian Aboriginal societies have been contested, for example, Rowland (1987:38–39; 1999:13, 33) was an early critic of the use of neo-Marxist interpretations which argued for the primacy of social relationships, internal structural change and dismissed the significance of environmental influences. Also, in response to arguments for a late Holocene intensification, Hiscock (2008:250–251) argued that the available evidence indicates that Pleistocene people were more diverse than previously thought and dynamic social change was not confined to the late Holocene in Australia, as evidenced by:

> …large congregations of people, specialised foraging strategies and small territories in some times and places, regional differentiation in art and technology, and labour intensive processing of plants such as grass seeds and Macrozamia.

[And]:

> …the archaeological evidence [for a late Holocene intensification] is equivocal, often representing overly enthusiastic interpretations of ambiguous archaeological records supplemented by an emphasis on historical observations and lacking consideration of interpretational difficulties…

Hiscock (2008:42–45, 249–252, 264–267) argued that archaeologically invisible factors such as power relationships, hierarchical controls and individual motivations are subject to personal interpretation (see also Hiscock and Sterelny 2023; Holdaway et al. 2008:403, 411; Ulm 2013:182–189). Consequently, the identification of internal social dynamics through the archaeological record of past Aboriginal groups is difficult to prove and is consequently very speculative, especially when attempting to translate ethnographically derived socio-cultural organisation into the deep past. As Ulm (2013:182) has observed:

> Accounts of long-term cultural change in Australia have emphasised the late Holocene as the period when ‘complexity’ emerged amongst foragers in Australia, associated with increased economic productivity, reduced mobility, population growth, intensified social relations and cosmological elaboration. These reconfigurations have often been interpreted as the result of continent-wide trajectories which began in the mid-Holocene, often termed ‘intensification’.

[And intensification]:

> …approaches have been found wanting as they homogenise diverse records of human adaptation into a single account which inexorably leads to the ethnographic present. The archaeological record tells a

> rather different story with fluctuating occupational intensity and even regional abandonments featuring in well-documented archaeological records. Instead, variability documented in the ethnographic and archaeological records can be understood as a product of local adaptations reflecting the operation of historically situated systems of social organisation in diverse environmental settings.

Other research has provided evidence which indicated significant variation in Australian climate patterns during the mid to late Holocene period (e. g. the onset of ENSO driven variability from about 4000 cal BP) providing opportunities to test these interpretations in a regional context such as at Calperum (Gell et al. 2005; Gingele et al. 2004, 2007; Petherick et al. 2013:69–70; Shulmeister and Lees 1995; Tibby et al. 2006).

8.10.2.2 Intensification at a sub-regional level—a local alternative

Responses by people to external and internal influences can be deduced from behavioural change evident in the archaeological record. Such influences could include the impact of pandemic disease, severe and extended drought resulting in ecological collapse, intra and inter group conflict, major environmental issues such as sea-level rise, a change in local or newly introduced belief systems, demographic pressures and new trade relationships (Hiscock 2008:245–267). Interpretations made from the remains of earth mounds, in an appropriate local context, may imply cooperation, socio-economic reorganisation and the deployment of technical and social innovation as argued previously in this thesis. However, archaeological interpretations can be skewed because of issues with preservation and sampling bias, as for instance, in the interpretation of rock art styles and the destruction of older archaeological deposits (Hiscock 2008:254). Interpretations must rest securely on the evidence presented with due consideration of observer bias such as personal belief systems and intellectual paradigms (Kuhn 1962).

In his critique of 'continental level' archaeological research in Australia, Ulm (2013:183–185) provided useful observations emphasising that 'regional cultural trajectories need to be disarticulated from the continental narrative to enable independent characterisation of local behavioural variability'. He highlighted the need to address chronological control, sampling and taphonomy and suggested that researchers refocus on open sites as well as the usual emphasis on rock shelter deposits in order to gain a greater picture of regional trends (Ulm 2013:187). Ulm's (2013) comments have a general resonance and relevance to the archaeology of all environmental zones including wetland environments where earth mounds occur. Earth mounds are one expression of a typological continuum of open sites which have been under-utilised as a potential source of information on regional socio-economic trends during the mid to late Holocene. This study has sought to address this gap as part of the wider study based in the Riverland region of South Australia outlined in chapter One.

Grand narratives, by their nature, are hierarchical, generalising, complex and involve the homogenisation of data, tenuous interpretations and a disregard for the small scale. This, of course, is where the methods of archaeological practice are applied, results recorded, and interpretations best formulated (Hiscock 2008). The study detailed in this thesis demonstrates that a consideration of socio-economic and cultural processes can be informed by behavioural changes within Aboriginal groups, which are visible in the archaeological and environmental records. For example, changes in behaviours signalling a likely transition in subsistence systems identified by this research at Calperum. I argue therefore, that the generation and implementation of technical, logistical and social innovation by individuals and groups, at sub-regional level, can lead to the modification of existing socio-economic and cultural systems, traditions and values. The evidence of such innovations by Australian Aboriginal peoples includes the logistic expansion of seed grinding, the establishment and operation of earth mounds, the channels and basins associated with eel husbandry and harvesting, stone fish traps and the remains associated with the complex processing of nuts that are toxic when consumed raw (Asmussen and McInnes 2012; Jones et al. 2022; McNiven et al. 2012).

Consequently, innovations and changes in socio-economic-cultural organisation can be inferred by archaeological evidence which demonstrates the implementation of new procurement strategies and lifeways which require a significant reorganisation of group resources. Such would be the case in a transition from a focus on traditional hunting and gathering, including mussel harvesting, to other strategies such as the large scale exploitation of emergent macrophyte resources as suggested on the Calperum floodplain. Locally derived social processes underlying invention and reinvention, and the generation of new tools (such as the tula) and new ways of procuring resources (as, for example, in the development of earth mounds, the harvesting of eels, fish traps and the processing of toxic nuts) are often overlooked in the development of continental level and homogenised models of intensification (Asmussen 2009, 2010, 2012:93–103; Beaton 1977, 1982, 1985; Ferrier 2015; Ferrier and Cosgrove 2012; Frankel 1995:652–653; Haberle and David 2004; Jones et al. 2022; Lourandos 1983, 1997; Smith et al. 1993; Tibbett 2004; Tuechler et al. 2014; Veth et al. (2011:10–11).

The next section relates evidence of technical, logistical and social innovation by Aboriginal people at Calperum to climate research in the context of small group dynamics as an alternative to the 'continental socio-economic intensification' models presented and discussed previously.

8.10.3 A social response to challenge–innovation, climate and earth mounds–a new model?

Innovation as a process is a broad concept encompassing technical, social and cultural components. As a contemporary example, complex and innovative socio-cultural processes can be demonstrated in current societies, as for example, the recognition of global climate change as a threat to modern socio-economic, cultural and political structures; and the current move to renewable sources of energy and the phasing out of fossil fuels as a possible response. Internally generated changes in socio-cultural perspectives and their influence on social trajectories can also be readily identified in both modern and premodern societies. Examples of such, include the improvement in public health through the campaign against tobacco smoking and the spread of new or modified religious practices during the Reformation. The process of innovation within human groups typically occurs in a nexus of internal and external influences. In a modern socio-economic structure, technical innovation is often a formal process initiated in response to changing market or social environments and ultimately directed to the needs of stakeholders. Such needs are researched, analysed, interpreted and usually fulfilled through a complex and bureaucratic process. On occasion, a simple isolated idea can lead to significant market disruption and the creation of significant value for stakeholders, albeit usually through the subsequent application of large amounts of capital and effort (Millar et al. 2018:254–260). Lubberink et al. (2018:52–78) detailed processes which apply to modern social contexts, where social entrepreneurs strive to engineer solutions to complex social changes. In essence these are oriented toward the generation of ideas (anticipatory governance of innovation) and the engagement of stakeholders through discussion and persuasion (Lubberink et al. 2018:67–68). Such principles are universal with the addition of coercion as a necessary requirement in autocratically structured societies dominated by totalitarian doctrines.

De Deu and van Dijk (2018), in their study of landmark discoveries in science and technology during the period 1500–1900 CE, found that:

> …rates of innovation are higher during prolonged periods of cold (versus warm) surface temperature and during the presence (versus absence) of volcanic dust veils.

[and],

> …the relation between harsher climate conditions between 1500–1900 CE and more innovation is mediated by climate-induced economic pressures and resource scarcity.

For early human societies, Kuhn (2012:75) argued that the ability to innovate within a given population is related to population size and population stability, such that:

> Periods of apparently slow behavioural evolution, characteristic of much of the record prior to (and arguably after) the origins of *H. sapiens*, could stem partly from the fragility of local populations…

[however],

> …periods of accelerated change and diversification [through innovation] could reflect greater continuity and robustness of local populations in the face of environmental fluctuations.

Social dynamics and cultural decision-making processes have been increasingly recognised by Australian archaeologists as influences for change within Aboriginal societies. Such processes would invariably include the generation of new ideas, techniques and new ways of organising group resources to address existential and lesser challenges. The innovation represented by the repurposing and change in logistic scale of heat retainer technology, represented by the formation of earth mounds in specific wetland environments, is an example of a relevant but decentralised social process. This operated at the level of the group, by virtue of context and purpose. (i.e., decisions and choices which are applied to foraging activities and take place on a day to day basis in the process of provisioning such groups).

Aboriginal societies were not 'passive participants in their own history' (Brian 2006:113), but were innovators in both products and processes, the latter including socio-cultural reorganisation in response to external challenges as is inferred for Calperum (Jones et al. 2022). However, interpretations involving internal political relationships and hierarchical stratification based on the control of production is speculative and arguably a distortion, given the difficulty of identifying past social relationships from a fragmentary archaeological record (Hiscock 2008:256–259; Smith 2013:42). For instance, Pate (2006) concluded from a bone isotope study of ancestral remains found at Roonka near Blanchetown on the River Murray (Figure 6.1a) that there was no indication of hereditary, stratified political structures demonstrated by the diet or lifestyle of the individuals studied, as had been argued previously by others (see Pretty 1977; Pretty and Kricum 1989). However, Pate et al. (1998b:26) also concluded that bone collagen stable nitrogen and carbon isotope studies indicated gender and age were associated with differences in intra-group diets. For instance, the diets of adult males differed from adult females and pre-adult juveniles with the latter group consuming greater quantities of $\delta^{13}C$-depleted foods such as aquatic and terrestrial plants and freshwater shellfish than adult males.

The various approaches to this debate can be explored through the consideration of an integrated study using multiple lines of evidence as is demonstrated by the research detailed in this thesis. The techniques and results reported here have provided a temporal framework and evidence for a change in subsistence strategies at Calperum which correlates to the onset of adverse ecological conditions from ~3800 cal BP. The evidence presented adds to the current understanding of the first establishment of this subsistence system at c. 4800 cal BP in the western Hay Plains and its later adoption in the wider MDB. This premise will be further discussed below.

As argued, adverse climate change or extreme weather events are factors which cannot be ignored as an influence on the resource base of a hunting-fishing-gathering society (or any other society for that matter) (Asmussen and McInnes 2013; Giddens 1983:166–167; Hiscock 2008:266; Hiscock and Sterelny 2023; Jones et al. 2022; Veth et al. 2000:61–62). Clearly, this is evident if a strong relationship can be demonstrated between climate and ecological change and the mobilisation of a specific socio-economic-cultural response which is visible in the archaeological record (Turney and Hobbs 2006). The initiation of an earth mound on the Calperum floodplain at ~3800 cal BP, in response to a loss or depletion of traditional resources as a consequence of ecological change, is evidence such relationships can be demonstrated. Such developments are strategic and indicate a novel socio-economic response by Aboriginal people, thereby demonstrating a broadening and/or intensification of economic activity in a local context. It can be further argued that the local implementation of technical and/or social innovation is a strategic process which can result in socio-economic reorganisation within an Aboriginal society in response to both external and/or internal challenges. Importantly, it indicates that such innovation was likely applied at group level, involving the co-operation and reorganisation of individuals, who in the case of the large scale development of heat retainer cooking were most likely to be women.

8.10.4 Innovation and change as a fundamental characteristic of Aboriginal societies

Lourandos (1983, 1985, 1997) introduced a different way of conceptualising Aboriginal societies, through the creation of a new paradigm about Aboriginal peoples and the information that was represented in the material record. Lourandos' work served to emphasise that Aboriginal peoples were able to vary their responses in multiple ways to address external and internal challenges, climate variation being but one. Such responses included the abandonment of marginal regions and a retreat to refugia as typified by Veth's (1989) 'refuge, corridor and barrier model of settlement' during the LGM. Recent analysis of settlement patterns, in the Riverland of South Australia (Westell et al. 2020; Westell 2022), has indicated changes in landscape and resource use in response to climatic variability over the period 29,000–12,000 cal BP, showing a:

> …nuanced occupation in the central Murray with Lake Victoria perhaps acting as a more continuous node and the Riverland on the periphery of this region.

Aboriginal people living in the Riverland region potentially dealt with climatic extremes during the LGM through high levels of residential mobility and flexible resource procurement strategies (Westell 2022:342–343). In societies based on hunting, fishing and gathering with low group numbers and relative flexibility, the organisation of internal group socio-economic resources should allow quick lead times once a need is generated and recognised as an issue of survival (e. g., reduced access to key resources in a rapidly changing environment). In such societies, it is the input of human capital through a socio-economic (re)organisation and the application of new ideas, human expertise and physical effort to the identification of new, under-utilised or repurposed raw materials, in response to internal or external stimuli (for which the establishment of earth mounds at Calperum is a prime example). A South Australian example, in a much earlier context, is the range of innovations which were demonstrated at the Warratyi rock shelter in Adnyamathanha country located in the northern Flinders Ranges (Hamm et al. 2016). Hamm et al. (2016:1) argued that cultural innovation was demonstrated in the early (49 ka) occupation of the Australian arid zone. This was indicated by the early use of ochre (49–46 ka), gypsum pigment (40–33 ka), bone tools (40–38 ka), hafted tools (38–35 ka) and backed artefacts (30–24 ka) at the Warratyi rock shelter (Hamm et al. 2016:1–3). Hamm et al. (2016:3) further argued that:

> …Warratyi rock shelter reveals evidence for the development of modern human behaviour in Australia and Asia.

[And]:

> Important technological innovations and early symbolic behaviour reveal that a dynamic, adaptive Aboriginal culture existed in arid Australia within a few millennia of settlement on the continent.

The use of Warratyi rock shelter by small groups on an ephemeral basis reflects a high level of residential mobility in a challenging environment. The innovations represented in the development and use of the materials and artefacts detailed by Hamm et al. (2016) hints at changes in socio-economic and cultural practices which facilitated the early entry and settlement of the Australian arid zone by Aboriginal people. The challenges posed by the environmental conditions of this region would have required the acquisition of new knowledge about water supplies, plants foods, medicines and hunting strategies. Both intra and inter social relationships would have been modified allow access to the territories of other groups to mitigate risks such as fluctuations in resource availability.

As a later example of innovation, the sudden appearance in the Australian arid zone of a type of hafted stone adze labelled a ‘tula’ at c. 3700 cal BP was argued by Veth et al. (2011:10–11) to be associated with the intensification of ENSO weather patterns across Australia. Veth et al. (2011:12) further argued that:

> The archaeologically ‘sudden’ appearance of tulas, without evidence of precursors, may be indicative of a strategic innovation in response to altered economic and social circumstances.

The innovation associated with tulas was related to an increase in residential mobility and was a component of a ‘risk minimisation technological strategy linked to increased environmental stochasticity’ (Veth et al. 2011:12). The tula was an entirely new tool type which rapidly spread through the arid zone, arising from the advent of new environmental conditions which ‘altered the economic and social circumstances’ of the Aboriginal peoples living in that environment (Veth et al. 2011:12).

The invention of the ‘tula’ has close parallels to the development of Aboriginal earth mounds at Calperum at about the same time and potentially related to the same decline in climatic conditions identified by Gell et al. (2005) for the South Australian Riverland. Technical and social innovation by Aboriginal people was arguably a routine response to threats and challenges, creating novel solutions through the invention of new and/or modification of existing technologies, and the reorganisation of human resources at group and clan levels.

The generation of new ideas in response to internal stimuli is arguably stimulated by external influences but can rise independently or as a response to a particular situation. Socio-cultural innovations can be expressed in the form of new knowledge and understanding, rituals, new socio-economic strategies, art forms, language, tools and technologies which then can spread externally through social and cultural links and trade. The latter, for instance, is the explanation generally extended for the introduction and spread of the Pama-Nyungun language group to many regions within Australia from about 6000 cal BP (McConvell 1996, 2020). The identification of the spread of a new linguistic system, without a large scale movement of people, demonstrates the existence of extensive social and cultural networks at that time. The socio-cultural flexibility, economic capabilities and socio-cultural networks of Aboriginal peoples provided an outstanding ability to respond to repeated challenge. This was an adaptive capability which ensured the survival and on-going success of Australian Aboriginal societies over the long term in both regions with extreme environments and more temperate regions periodically subject to adverse weather events.

8.10.5 Section summary

Frameworks that insist on predetermined explanations for change can be unhelpful in establishing interpretations for changes in the behaviour of past societies. A socially based neo-Marxist theoretical framework for past Aboriginal societies, involving the hierarchical control of production (subsistence in this context) and resultant complex social and political relationships, is a modern construct, which potentially can distort interpretations of the past history of Australian Aboriginal societies. To discount the role of climate and ecological change and to argue for the primacy of internal processes likely lacks nuance. Arguments for economic reorganisation and outcomes derived from complex political and social relationships, as the primary factor in socio-economic-cultural change, is an unnecessary and overly complicated way to explain the dynamics of change in social structures characterised by small groups in a continent subject to highly variable climate regimes. Clearly, as argued previously ecological disruption associated with climate change would have been at least a factor of some consequence to local groups who find their subsistence systems under threat.

However, the debates such as those initiated by Lourandos have served to deliver a much more nuanced understanding of the past. Brian (2006:113) articulated this as the most important element of Lourandos' contribution, where he argued that:

> This representational dimension of intensification is a bold step away from earlier ways of seeing past Aboriginal culture. It holds that, rather than understanding Aboriginal culture *a priori* as a generally stable and conservative way of life governed by the dictates of a harsh climate, much can be gained by envisioning a more active, more dynamic way of being that exercises cultural choice in determining relations to the land, to its resources, and to other people.

Aboriginal societies were capable of mounting innovative responses to challenges which have been evident since the entry of their ancestors into this continent at around 65,000 cal BP (Clarkson et al. 2017), and retained this dynamism up until European invasion. This research has demonstrated a clear causal link between climate variability, consequent ecological change and an innovative socio-economic response by local Aboriginal groups at Calperum. Prior to this work little research had been conducted into such responses in the MDB and constitutes an opportunity for further work in this region. Such links demonstrate the relevance of investigating climate and associated ecological change as a potential factor behind behavioural change in past Aboriginal societies. Responses by Aboriginal groups in other regions have included relocation (e. g., refuges, corridor and barrier model), the implementation of new or modified stone tool technologies and existing techniques such as mosaic burning to improve hunting returns and regenerate food plants. In addition, new or modified subsistence strategies (e. g., earth mounds, toxic nuts, seed grinding, fish traps and eel husbandry) were developed to address short and/or long term environmental and/or demographic influences on the availability of subsistence resources to individuals

(Asmussen 2009, 2010, 2012:93–103; Beaton 1977, 1982, 1985; Ferrier 2015; Ferrier and Cosgrove 2012; Frankel 1995:652–653; Haberle and David 2004; Jones et al. 2022; Lourandos 1983, 1997; Smith et al. 1993; Tibbett 2004; Tuechler et al. 2014).

The presence of many surveyed earth mounds (n > 55) demonstrates the scale at which Aboriginal people engineered available wetland microenvironments on the floodplain at Calperum from at least 3800 cal BP. These operated as seasonally intensive sites for the production of large quantities of carbohydrate and fibre derived from dense stands of *Typha* established and managed though techniques such as those outlined by Gott (1999:42), including fire and digging which allowed:

> …the penetration of litter and ash from firing, and loosened and aerated the soil, all of which promoted new growth. Regular removal of the rhizomes provided space for new growth and seed germination…

An early historical account by Grey (1841 2:292) suggested a level of complexity and detail in the management process associated with the exploitation of *Typha* rhizomes:

> …they [Aboriginal people] bestow a sort of cultivation upon this root [*Typha*], as they frequently burn the leaves in the dry seasons, in order to improve it.

The growth in scale of earth mound use at Calperum is indicated by the close spatial relationship of two similarly aged mounds HIS_2_22 and HIS_2_23 amid the overall concentration of mounds around billabongs located near the main river channel in the southern section of Hunchee Island (Figures 6.1a, c). Mound placement indicates the local scale of seasonal use of these billabongs in the past for rhizome harvesting and consequent production of carbohydrate and fibre (Jones 2016; Jones et al. 2017; Jones et al. 2022). The evidence suggests a stable but seasonally and climate mediated example of food and fibre production which persisted for at least 3800 years at Calperum including during extended periods of environmental variability.

8.11 A consideration of broad spectrum diets and Intensification theory in relation to the evidence from Calperum and the wider MDB

8.11.1 Introduction

The introduction of BSD in western Asian contexts was argued to be associated with a shift in diet choice involving a switch from larger to smaller prey and the incorporation of greater quantities of plant food in local subsistence systems prior to a transition to agriculture (Bird et al. 2016; Edwards and O'Connell 1995; Flannery 1969; Zeder 2012). Ethnohistorical accounts indicate that carbohydrate from seasonally available grass seeds and USOs was a ubiquitous and major component in Aboriginal diets, where available, at the time of contact, including the USOs of various species of terrestrial yam and the rhizomes of freshwater species of emergent macrophytes (Angas 1847; Beveridge 1865, 1883, 1889; Kirby 1895; Clarke 1985; Gott 1982, 1983; Grey 1841 2; Macintyre and Dobson 2019; Mitchell 1838).

Florin et al. (2020:5) reported early plant processing and consumption at Madjedbebe rock shelter in northern Australia, including:

> …fruits, nuts, USOs and likely seeds at Madjedbebe 65–53 kya, [which] does suggest that a broad diet was part of the toolkit employed by the EMH populations who reached Sahul 65,000–53,000 years ago.

Florin et al. (2020:2) argued that current evidence for plant use in Sunda and Sahul during the Pleistocene favours a dispersal model for early modern humans which:

> highlight early adaptations to non-coastal environments by EMHs leaving Africa, including to more extreme ecosystems (e. g., rainforests, high-altitudes and deserts).

[And],

> …because the intensive and multi-step processing techniques required to make the identified plant foods edible are indicative of both complex and flexible foraging, and the kind of broad diet that underpins adaptations to more difficult environments.

[Concluding],

> …that Australia's earliest known human population exploited a range of plant foods, including some requiring processing. Our findings have implications for understanding EMH behavior, cognitive flexibility and subsistence strategies at the eastern end of the modern human dispersal arc.

Evidence from residue usewear and traces from a grinding stone assemblage at Madjedbebe is older than that identified from previous research at Cuddie Springs and Lake Mungo by about 35,000 years (Fullagar and Field 1997; Fullagar et al. 2015). Florin et al. (2020) argued that the evidence at Madjedbebe and later evidence in Southeast Asia and Sahul indicated:

> …that plant exploitation was a fundamental aspect of EMH diets globally. Culturally transmitted botanical knowledge, and the cognitive ability to perform multi-step and intensive processing sequences likely contributed to the adaptability and flexibility required by EMH populations to traverse continents and colonise new environments around the world.

The evidence from Madjedbebe indicates that BSDs have a long history in Australia, including resources such as USOs, nuts and seeds where complex processing is required to access the available nutrition. This has enabled Aboriginal people to respond to opportunity and challenges when encountered. In this sense the incorporation of new foods and the implementation of new ways of processing existing foods has its roots in past practices. Evidence of the use of a wide range of seasonal plant foods in local diets reflects an extensive ability to address variability of supply in both the short and long term. This was achieved through existing or new management strategies, the introduction of new or previously marginal foods, socio-economic/cultural reorganisation, the repurposing of existing techniques and/or the generation of new ideas and new ways of procuring resources. In this sense, it can be argued that Aboriginal peoples have always exploited a diverse repertoire of resources which represented a spectrum of diet options and subsistence strategies in a multitude of variable local environments since first entry to the continent.

The success of Aboriginal peoples in adapting to multiple environments in the Australian continent is a testament to the strength, dynamism and capacity for technical and social innovation of past Aboriginal societies. The archaeological record repeatedly demonstrates the underlying ability of groups and individuals to innovate, organise and adapt to the challenges imposed by change, whether imposed by environmental variability and/or intra and inter group dynamics. Solutions devised to address adversity most certainly involved the marshalling of social and cultural resources and the implementation of technical and/or social innovations as necessity dictated.

8.11.2 Broad spectrum diets in the Murray Darling Basin: A broadening of diet at Calperum?

8.11.2.1 Background

The broadening of diets by Australian Aboriginal populations from the mid Holocene, has been argued to be a response to environmental challenges and/or demographic and social factors which emerged at this time in support of higher population growth trajectories from the mid Holocene optimum (Edwards and O'Connell 1995; Haberle and David 2004; Williams et al. 2015a, b). This study, through a focus on a specific wetland environment at Calperum, has identified broadened resource exploitation likely associated with the introduction of innovative management and processing techniques which allowed the efficient extraction of nutrition from previously marginal, low trophic plant foods. The presence of freshwater mussel shell lenses under mound HCN20 dated to ~ 3800 cal BP indicates the availability of this resource at this time and closely correlates with the establishment of the oldest (to date) mound (HIS_2_21) at Calperum. Evidence of climate change and a decline in mussel availability within floodplain environments at Calperum from ~3800 cal BP until ~2500 cal BP as argued previously serves as an indicator for a general decline in resources over this period. I argue that the emergence of a food production system based on heat retainer technology was a response to a decline in other subsistence resources on the Calperum floodplain and possibly in other regions of the MDB at other times. This was due to variations in climate and consequent ecological change, and ultimately induced a socio-economic-cultural reorganisation to address a shrinking resource base. Socio-economic reorganisation is suggested by the level of effort, commitment and co-operation which would have been associated with the development of the (repurposed) heat retainer based food production system. The concept of production in this context is analogous to the processing stage in modern food manufacture where raw materials are prepared for packing and consumption. Harris (1975:849) critiques the distinction often made between procurement (gathering) and plant food production (agriculture) which ignores the potential for logistical and technical innovation and associated changes and innovation in social and cultural organisation within hunter-gatherer societies. Harris (1975) argued that such changes can occur without crossing the social, cultural, political and economic thresholds associated with the development of agriculture. This clearly provided an alternative socio-economic framework for the development of more complex social and cultural systems as demonstrated in the Australian continental context.

It possibly took time to reach the scale of organisation displayed by the level of management, harvesting and cooking detailed by early European observers in the mid-19th Century, which is potentially reflected in the age profile of the sample of mounds selected for this study, which show an increase in mound establishment from~1000 cal BP. Alternatively, taphonomic processes and the relatively small sample from Calperum likely under-represents the scale of mound establishment and use. However, by the time of contact, the cooking of *Typha* rhizomes in the MDB had reached an almost ‘industrial’ scale

(Beveridge 1889; Kirby 1895:2728; Mitchell 1839:80–81, 134). This was likely enabled by the amelioration of climate after 2500 cal BP which, incidentally, also saw the recovery of mussel habitat on the Calperum floodplain as demonstrated by the growth in midden deposits after this time (albeit with some punctuation as indicated in Figure 8.2) (Westell et al. 2020; Westell 2022). However, once established the food production system founded on the exploitation of a managed natural resource (*Typha*), a scalable technology (ground ovens) and a socio-economic reorganisation (labour) persisted and expanded into the available ecological niches provided by the anabranch fed system at Calperum.

Field surveys of the Calperum floodplain conducted over the period 2015–2021 indicated an absence of emergent macrophyte species within the floodplain except for isolated stands in the anabranch creek system, lakes and regulator channels. This probably indicates the impact of the modern regulated river system, less frequent inundation of the floodplain and the absence of Aboriginal management practices which supported the local production system based on emergent macrophytes. The age ranges 295–0 and 283–0 cal BP, of the younger mounds HIS_2_22 and HIS_2_23 respectively (Figure 7.4) indicates that these practices were still active close to the time of European invasion.

Figure 8.3: Calperum landscape containing regenerated *Typha* (left image) following irrigation of a low lying area northwest of Hunchee Lagoon and adjacent to higher ground containing hearths (right image), middens and eroded earth mounds. Photographs R. Jones April 2021.

It was noted during the field component of this study that on the irregular occasions when water was released into low lying areas north west of Hunchee Lagoon, as part of a landscape management program, *Typha* quickly regenerated in these locations after inundation (Figure 8.3). This demonstrates the resilience of this genus and its capacity to provide large quantities of carbohydrate for Aboriginal people. *Typha* has similarities to the way rice is cultivated in an irrigated paddy environment but differs since it involves management of an existing and natural ecological niche rather than assisted seeding and cultivation. After harvesting it is immediately cooked rather than threshed and has limited ability to be stored, unlike rice grains which can be stored for extended periods in dry and sealed environments prior to cooking.

8.11.2.2 A transition in subsistence and a broadening of diet?

The Hunchee Lagoon earth mounds are located in a linear cluster (n = 12) extending more than two kilometres along the northern bank of the Lagoon which forms the north-eastern extremity of the Ral Ral/Hunchee Creek anabranch system (Figure 8.5). The cluster contains mounds HCN20 and HCN21 which were excavated as part of this study and HCN25 which was the subject of a geophysical analysis by Ross et al. (2019). There was little surface evidence of mussel shell midden deposits along the northern bank of Hunchee lagoon during initial surveys for mounds conducted for this research. This was in contrast to extensive middens located to the south along the bank of the main Murray River channel and isolated midden deposits associated with other cultural material such as stone artefacts and/or hearth remains in sandy locations on Reny Island, Hunchee Island and north of the Ral Ral Creek/Hunchee Creek anabranch system (Westell pers. comm. 2021; Westell et al. 2020).

The paucity of evidence of shell deposits and smaller quantities of fragments apart from the shell lenses of *V. ambiguous* (lacustrine species) present at about levels 3–6 of the HCN20 and level 3 of HCN21 excavations, suggested high mussel availability in the immediate area was potentially restricted to the period prior to ~3400 cal BP and after ~2500 cal BP (Tables 7.2A, 7.2B, 7.4 and 8.2; Figure 8.2). Given the change in climate conditions identified at Tareena Billabong was noted at ~3800 cal BP (Gell et al. 2005), this potentially indicates a slow decline in water availability at Hunchee rather than an immediate impact. The pollen evidence (Figure 7.18) from the excavated mounds at Calperum discussed previously (with caveats), indicates the dominance of low growth shrubs around 3800 cal BP with higher canopy trees dominant by ~500 cal BP, with a transition evident at ~1000 cal BP (Table 8.1). The evidence suggests a cumulative process of lower water availability across the Calperum flood plain from ~3800 cal BP which then began to ameliorate after ~2500 cal BP. The minimal presence of discarded mussel shell, indicated by the dating evidence, across the

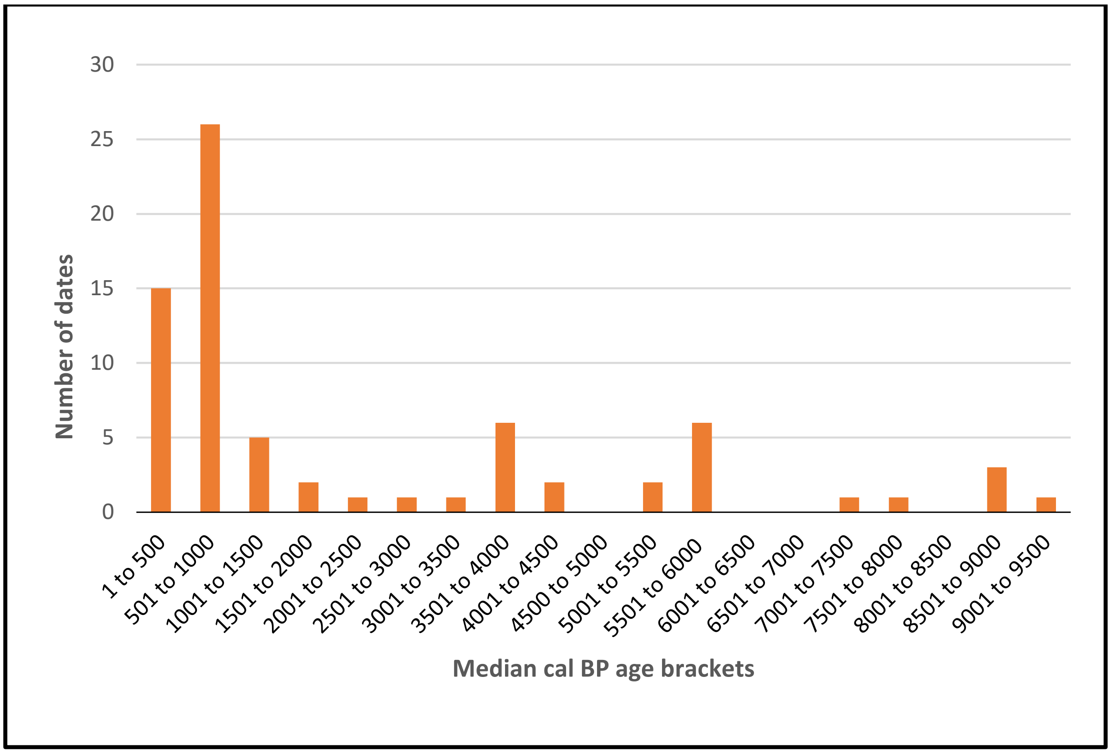


Figure 8.4: Combined plot of shell ages (calculated as a median of the calibrated range) in 499 year brackets for the period from 9500 cal BP, from midden and mound sites on the Calperum floodplain (Tables 7.4 and 7.5; see also Westell et al. 2020*;* Westell 2022:516–517).

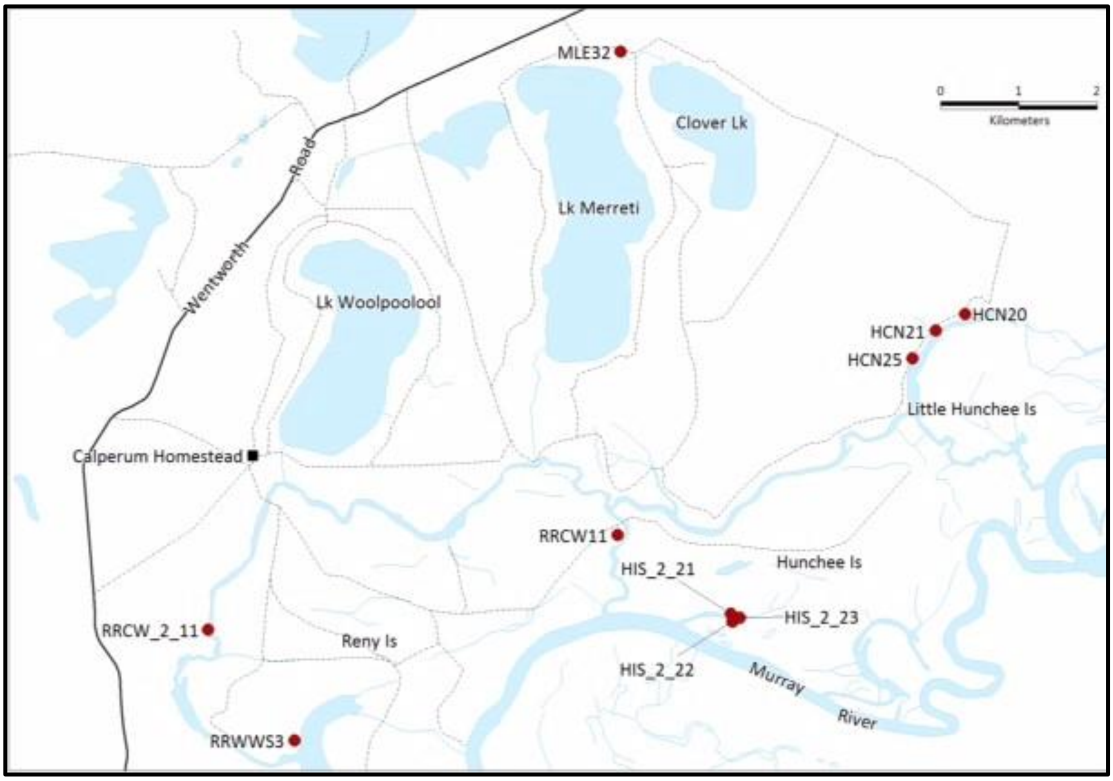


Figure 8.5: The spatial arrangement of mounds at Calperum, showing the location of HCN 20,21 and 25 which are representative of a 2 kilometre linear cluster along the northern bank of Hunchee lagoon (the other 9 mounds of the cluster, HCN19, HCN22–24, HCN26–30 are not shown).

floodplain during the early Holocene demonstrated in the shell age data (Figure 8.4) is possibly related to taphonomic processes related to higher river flows during this period. Such episodes are indicated by the presence of the scouring pattern associated with the northern end of the Hunchee Lagoon which is considered to have been active from at least ~8000 cal BP (Figure 8.1) (Westell pers. comm. 2021).

However, the evidence indicates lower water availability and ecological decline as the likeliest explanation for the depletion of terrestrial and aquatic resources at Calperum after ~3800 cal BP as outlined previously. In addition, a transition between subsistence systems/lifeways evidenced by the establishment of mound HIS_2_21 at 3981–3723 cal BP in the southern portion of Hunchee Island (Figures 6.1a, c and 8.4) suggests a deterioration in traditional resources and also a broadening of diet for Aboriginal people at Calperum virtually from the onset of ENSO variability from ~3800 cal BP. The establishment of a large-scale and labour intensive food production system which operated seasonally in accordance with the availability of aquatic rhizomes also represents a local resource replacement strategy at Calperum which developed from this time. Under this premise, the emergence of earth mounds which were created from the repeated use of earth ovens in the one location, is the likely signature of a reduction in the availability of traditional resources and a new focus on aquatic rhizomes as an alternative resource from ~3800 cal BP. The efficiency and productivity of the new system ensured that it persisted into the late Holocene and was ultimately cemented as a major seasonal component of the local resource repertoire after the return of more favourable climatic conditions.

8.11.2.3 Mound development in the wider MDB and elsewhere

Kuhn (2012:76) emphasised the importance of connectivity through social networks (both internal and external to the group), for the dissemination of new ideas and news ways of doing things. On the available evidence, the repurposing of heat retainer technology which enabled a transition in subsistence strategies in some riverine environments in both the north and southeast of the Australian continent, occurred at ~5000 cal BP. It is possible that the initiation of mounds in the western Hay Plain was related to the diffusion of knowledge from the north (or vice versa) given the existence of extensive networks through the continent c. 6000 cal BP as demonstrated by the linguistic evidence previously discussed (see also McBryde [1984] for a discussion on early evidence of long distance trade networks and Westaway et al. [2021:1055–1057] for a similar discussion of long distance trade in lithic materials by peoples in the south-western region of Queensland). My hypothesis is that it is equally possible that these developments were related or arose independently. In the latter instance, the independent appearance of mounds in the north and southeast of the continent could have been analogous innovative responses to similar circumstances associated with climatic variability.

8.11.2.4 The MDB context

I have argued for the implementation of technical and social innovation, and a broadening of diet in response to climatic and ecological change at around 3800 cal BP on the Calperum floodplain, as indicated by climate research and the dates obtained from shell obtained from the mounds HIS_2_21, HCN20 and HCN21. In the wider MDB, Martin (2006, 2011) demonstrated that the innovation associated with the nexus between heat retainer cooking and *Typha* potentially emerged about 1,000 years earlier, near Balranald in the western Hay Plain region (Figure 2.10) The early ages obtained by Martin (2006) (ranging from 5319–4425 [WK4101] to 4143–3497 cal BP [WK-4098]) were from two mounds, Ravensworth 3 and Tchelery 1, located on the lunettes of a palaeo lake. Such a context is not a typical geomorphic context for earth mounds found in the Murray, Murrumbidgee and Lachlan River corridors. Available dates for mounds in the nearby central Murray valley, Murrumbidgee, Wakool and western Victoria are typically younger with only two in the Wakool and Murrumbidgee regions dating to between 2800 and 3500 cal BP (3366–2862 cal BP [Beta-7068] and 3481–2724 cal BP [ANU-7881]) respectively (Table 2.3). The apparent discontinuity in earth mound initiation and development within regions located near the western Hay Plain region for ~700 years after the youngest age of ~3800 cal BP obtained for the Tchelery 1 mound (estimated from median values from the age ranges above), may be a question of the intrusion of younger charcoal, lack of preservation or sampling bias. However, the oldest age obtained from mound HIS_2_21 at Calperum falls within this period and indicates the local use of this technology from this time.

The key questions I pose are:

1. Why did the earliest earth mound developments in Australia appear in the western part of the Hay Plain?

2. Why did it not lead to concurrent development in nearby areas such as the Murrumbidgee and central Murray regions (at least on current evidence)?

The youngest date obtained at Ravensworth 3 and Tchelery 1 suggests mound development ceased at around 3800 cal BP (4143–3497 cal BP, Wk-4098) and the mound was used for other purposes from that time (Martin 2006). It is possible that the discrete period of use, the unusual location and the large dimensions of these two mounds (Figures 2.5 and 2.6) indicate that very specific and local influences were a likely factor behind early emergence and abandonment of earth mounds in the western Hay Plain region. The onset of arid conditions in the MDB from ~5000 cal BP may have been a factor in this development (Fitzsimmons 2013:92; Petherick et al. 2013). In such a scenario, Aboriginal people at Ravensworth and Tchelery 1 likely transitioned early to a production system based on *Typha* rhizomes to augment traditional resources impacted by ecological change. This continued for ~1000 years then ceased. The onset of ENSO conditions at ~3800 cal BP which induced wet/dry cycles (as previously discussed for Calperum) potentially relates to this latter outcome. The drying of the associated lake system likely caused a decline in the availability of *Typha* and other aquatic resources in the vicinity causing local groups to cease this activity and revert to the exploitation of other resources. In contrast, at Calperum ENSO conditions appeared to induce the adoption of this production system at this time, again likely to be a response to local and specific circumstances. This reinforces the primacy of local circumstances as a major influence on differences in behaviour, in similar locations at similar times. This finding is contradictory to conceptual themes of temporal and continental level intensification trajectories.

8.11.2.5 Nuances in mound development in the MDB

Within the MDB there are temporal anomalies in the establishment and development of earth mounds which suggest nuances in the adoption of this technology and possible regional differences in the challenges effecting local Aboriginal groups. As indicated previously, a mound at Calperum has an operational range starting from ~3800 cal BP (HIS_2_21 at 3981–3723 cal BP [0ZZ566]). The age of this mound coincides with the youngest Hay Plain age but is located approximately 300 km to the west. The possibility exists that communication through regional networks transmitted knowledge of innovations associated with the repurposing of heat retainer technology and the consequent development of earth mounds to Aboriginal groups at Calperum. However, there is no evidence of the adoption of this technology by closer groups to the Hay Plain mound locations until about 700 years later than at Calperum. Of course, this anomaly may be a result of preservation issues in floodplains closer to the western Hay Plain region where taphonomic processes have destroyed the evidence of earlier mound development.

In the interim, and subject to additional research into regional mound ages, the current evidence suggests the innovation could have equally arisen independently within the South Australian Riverland region or could have been an extension of practices elsewhere. The development of mounds on the floodplain at Calperum most likely occurred in response to local climate variability and ecological change as discussed previously. Prior to the development of earth mounds, it is likely that aquatic plant rhizomes were a 'sometimes food' for Aboriginal groups at Calperum and in the wider MDB, which were cooked occasionally in isolated earth ovens which represented a basic practice from which mounds would later develop. Landscape surveys and a gradiometric survey did not identify such features at Calperum indicating that isolated earth ovens are likely to be invisible or indistinguishable from general hearth remains.

Earth mounds likely represent an extension of existing knowledge which was contained within a repertoire of traditional socio-economic techniques. The actual innovations involved were a logistical increase in the use of clay heat retainer associated with a readily available bulk supply of a food resource and a socio-economic reorganisation of labour. In combination, these components constituted a local adaptation to the onset to adverse conditions which resulted in a broadening of diet in the localities where it was established and persisted. The evidence from the western Hay Plain indicates a flexibility in the mobilisation of such innovations. When conditions dictated, innovative adaptations were independently generated or potentially generated from an existing knowledge base. When conditions changed Aboriginal people found new solutions, and at least in the central Murray and Murrumbidgee regions, apparently did not employ this technology again until ~ 3000 cal BP (Appendix Eight).

8.11.2.6 Why are there anomalies in earth mound establishment within the MDB?

The lack of evidence for earth mounds in the central Murray River region for ~800 years after 3800 cal BP, in contrast to the evidence at Calperum, may be related to dating anomalies associated with charcoal (as discussed previously in section 8.7.3). Alternatively, it may reflect a lack of survey and associated research in these areas, in which case a redating program to investigate this issue and validate (or otherwise) existing mound chronologies would be a priority. Geomorphological differences in the complexity of the floodplain environments in the central Murray region may also be a factor. For instance, the archaeological evidence indicates intensive use of the large, high resource Calperum/Chowilla floodplain complex of ephemeral lakes, anabranch creeks lagoons and billabongs which possibly supported a higher population density than the floodplains to the east (Jones et al. 2017; Jones et al. 2022; Westell et al. 2020; Westell and Wood 2014). At Calperum, the combination of a higher population density and a reduction in viable floodplain habitats for animal, mussels, birds and fish because of climate variability from ~3800 cal BP is a likely reason behind a change in behaviour involving the exploitation of emergent macrophytes as an alternate source of nutrition. As previously argued, a decrease in traditional resources likely occurred at Calperum from ~3800 cal BP due to climate change, potentially signalling a transition in procurement systems.

In the floodplains of the central Murray region to the east of Calperum, lower population levels and closer access to the main river channel may have allowed local groups to maintain their dependence on traditional resources such as fish, animals, crustations, birds, reptiles, plants and mussels. Consequently, this may have ameliorated the impact of periods of climate variability and reduced river flows associated with ENSO activity from ~3800 cal BP (Gingele et al. 2004, 2007; Petherick et al. 2013:69–70; Shulmeister and Lees 1995). The need to find alternative sources of nutrition was potentially less acute and consequently major changes in behaviour did not occur at that time. By ~3000 cal BP, increased climate variability potentially induced local groups to widen their diet options.

Ethnohistoric accounts indicate that extensive trade and exchange networks existed along the Murray River, its tributaries and nearby regions at the time of contact with Europeans (Batey n.d.; Beveridge 1983; Dawson 1881; McBryde 1984). Indeed, McBryde (1984:150–151) expressed surprise at the similarities between trade and exchange systems across the continent which incorporated commodities, marriages, services, songs, names and dances. McBryde (1984:148) also noted the existence of long distance trading networks which linked distant regions. While Aboriginal practices and customs at the time of European contact do not necessarily reflect the practices of the past it is noted that long distance trade in ochre and stone for tool making has a long history in Australia (Hiscock 2008:125, 189). Consequently, communication through local and regional networks would have likely provided knowledge of aquatic rhizome exploitation in those areas where it had previously become established, enabling other groups to adopt a similar strategy when required. On the basis of current evidence, including existing chronologies, I would argue that the widening of diets in the broader MDB was a choice which was exercised as required, at a group or clan level, in response to local factors, with groups at Calperum impacted and transitioning earlier than elsewhere in the MDB except for the initial establishment of mounds in the western Hay Plain region. This premise is a potential subject for additional research into the ages of Australian Aboriginal earth mounds within the central region of the MDB which will ultimately add clarity to the hypotheses presented here.

8.12 Chapter summary

This chapter has revisited the original focus and aims of this research in order to contextualise and interpret the results obtained from the analyses of mound contents and sediments excavated at Calperum outlined in Chapter seven. The discussion has considered the principal explanatory hypotheses formulated from the study of Aboriginal societies in Mid Holocene Australia. The arguments for and against continental level 'intensification theory' and the introduction of BSD at this time have been considered and appraised. A discussion of socio-economic and cultural behavioural change was informed by the results of the investigation into the archaeological remains of a subsistence procurement system based on large scale heat retainer cookery which, based on the evidence collected for this thesis, was established at Calperum ~3800 cal BP. Aboriginal people probably responded to adverse climate variability, resultant ecological change and reduced resource productivity through the implementation of technical and social innovation in this instance. Diets were broadened at Calperum through the exploitation of marginal plant foods using elements from an existing subsistence and technical repertoire encompassing both terrestrial and aquatic resources. At Calperum, such resources included seasonally available animals, birds, reptiles, fish, shellfish, crustations, and aquatic and terrestrial plant components; all of which were subject to climatic cycles which involved periods of flooding and drought. The more intensive use of emergent macrophytes represented a widening of diet in the sense of ‘scaling up’ an established Aboriginal technology and an existing but under-utilised resource. This was an example from a wider innovative repertoire which also included (in other locations) eminently scalable techniques such as grass seed grinding, nut toxin removal, eel husbandry, fish trapping and yam replanting. Such strategies were used in accordance with local circumstances in a variety of other places (for a wide discussion of the implications of ‘Aboriginal husbandry’ see Gammage 2011; Gerritsen 2008; Pascoe 2014: Rowley-Conwy and Layton 2011:850–851; Sutton and Walshe 2022).

However, the upscaling of these procurement strategies cannot be assigned to a specific event or ‘revolution’ (BSR) as was first proposed for early Holocene hunting, fishing and gathering populations in western Asia (Flannery 1969). For instance, the gaps observed in the radiocarbon age data associated with earth mound based procurement in the MDB potentially indicates a punctuated introduction of this innovation, indicating the primacy of local priorities and conditions for its adoption. Thus, discontinuities in the establishment of earth mounds in the MDB implies a discontinuity in trajectories of ‘intensification’ and the emergence of broader diets in this region. Consequently, late Holocene socio-economic intensification and the widening of Aboriginal diets in the MDB could possibly be more accurately described as locally determined, innovative and incremental phenomena. Such phenomena would have been subject to a multitude of local influences including climate variability and ecological change, demographic packing, social organisation, geomorphic variability in landscape and resource characteristics, and ultimately dependent on individual choices at different times for different reasons. More research will assist to clarify these ideas.

The inclusion of socio-economic and cultural factors as part of the composite of processes which commonly influence human individuals and groups are implicit in studies which investigate human behaviour and history particularly at the local level of groups and clans. This is the level at which the discipline of Aboriginal archaeology operates, rather than the homogenisation of data derived from a multitude of different local contexts, socio-economic systems, climatic zones, languages and art styles required for continental level modelling. I argue that behavioural changes demonstrated within the cultural and socio-economic systems of Aboriginal societies in some of the wetland environments of the MDB provide opportunities to study the implementation of technical and social innovation at local levels of organisation. Such innovation has been instrumental in offsetting the impact of adverse ecological change and demonstrates a continuity in the plasticity of resource use and diet choice. Flexibility in subsistence procurement supported the continuity of local Aboriginal lifeways, despite periodical adversity which arose from extreme climate variability. The behavioural change implicit in such flexibility was founded on the expression of new ideas and co-operation which potentially provided the basis for nuanced and differing regional trajectories of Aboriginal socio-economic growth from the mid Holocene.

Chapter Nine: Conclusions

9.1 Introduction

This thesis details an investigation of the archaeology of a sample of six Aboriginal earth mounds at Calperum, in the South Australian Riverland, which was conducted using an integrated approach using archaeological, geological and palaeobotanical evidence. The research sought to add to key debates about the development of Aboriginal societies in the Holocene. These focussed on a purported intensification of socio-economic activity and an associated broadening of diets which were argued to be a continental wide phenomenon visible in the archaeology associated with Australian Aboriginal societies from this period. In addition, the implementation of innovation at group level and the role of women was considered in regard to earth mound initiation and operation.

The analysis was conducted through a study of mound contents, including quantification of artefacts, faunal remains and other materials such as heat retainer and bioturbation nodules. Other methods used included radiocarbon dating, plant microfossil morphology, sediment grain size, pH, colour, magnetic susceptibility, LOI, pXRF and ICP-MS. The data generated from the methods employed were then correlated with the results of previously published climate research. This correlation has allowed interpretations to be formulated and advanced, in relation to practical and innovative responses to major ecological change by Aboriginal people living on the Calperum floodplain from about 3800 years ago. Major conclusions and recommendations for further research derived from this study are outlined below.

9.2 Calperum earth mounds and *Typha*

A subtle signature provided by pollen analysis and circumstantial evidence of rhizome use based on the presence of aquatic snail shell within the excavated Calperum mounds constitute the evidence available for the processing of *Typha* spp. in Calperum mounds. In this instance, the presence of aquatic snail shell in all six mounds was considered to be a viable proxy for the transference of aquatic plant rhizomes into earth mounds for ground oven cooking in addition to the conclusions of other researchers such as Klaver (1998) and Martin (2006). Further, given the evidence of the exploitation of *Typha* rhizomes by early

European observers on the Lachlan, Murrumbidgee and Murray Rivers, this was deemed to also be a likely principal plant food and fibre source for the oven mounds at Calperum. Of course, this does not preclude the casual cooking of other plant foods, fish, animals, crustations or shellfish in such mounds. However, the limited presence of snake and fish bone, yabby (*C. destructor*) gastroliths and fragmented mussel shell indicates cooking and consumption of such foods in small quantities only during periods of mound use. The low presence of artefacts, mammal, fish and reptile bone present suggests the major component of domestic cooking and consumption activity took place in locations nearby where base camps were established. As previously discussed, these would most likely have been established in sandy areas separated but within easy commuting distance of the 'dirty' earth mound processing sites (e. g., see Binford [1983:168] for a relevant discussion of such practices). The apparent differences in landscape use between Calperum and other MDB regions is a possible opportunity for further research.

9.3 The Calperum evidence—climate change, social reorganisation and BSD

The evidence obtained from the excavation of six Calperum earth mounds indicate that Aboriginal people adopted an innovative food production system on the Calperum floodplain at ~3800 cal BP. This was correlated to the beginning of an extended period of adverse climate and ecological conditions linked to the onset of ENSO related weather patterns at ~3800 cal BP and which began to ameliorate from ~2500 cal BP. A range of age determinations from this and other research (n = 63) on mussel shell obtained from mounds and middens on the Calperum floodplain clustered at ~3800 (n = 5) and after ~1500 (n = 43) cal BP although of course middens on the Calperum floodplain have a deeper antiquity (Westell 2022). This was interpreted as indicating a significant decline in mussel availability and other terrestrial and aquatic resources for local Aboriginal groups from ~3400 cal BP, for about 900 years, which likely provided the impetus for an alternative source of nutrition that culminated in the intensive exploitation of *Typha* rhizomes. In effect, the change to a procurement system based on the production of large quantities of carbohydrate on a seasonal basis is representative of a broadening of diets in this locality, at this time.

The range of age determinations obtained from the six excavated mounds at Calperum (Tables 7.4 and 7.5) and the presence of the remains of over 55 earth mounds on the floodplain (and over 235 for the Riverland region in total [Jones et al. 2022; Westell and

Wood 2014]), is evidence of the ubiquity of this production system. The appearance of earth mounds in other riverine environments in the wider MDB is argued to demonstrate replacement and/or augmentation of subsistence procurement systems within those locations from the mid Holocene. Replacement of depleted supplies of previously targeted resources did not necessarily constitute an increase in per capita productivity but did potentially skew levels of protein and carbohydrate which were consumed (for instance starch rich rhizomes vs mussels and other fauna) on a seasonal basis. The seasonal nature inherent in the availability of emergent macrophyte derived food is potentially linked to supporting larger gatherings rather than supporting population growth in the late Holocene as is posited by Intensification arguments (Beaton 1983, 1985; see also Bowdler 1981; Lourandos 1983; Lourandos and Ross 1994:54–55; Ross 1985; Ross et al. 1992; Williams 1988). The punctuated timing of the appearance of earth mounds in the MDB over the period 4800 to 3100 cal BP suggests the primacy of local conditions influenced the timing of the adoption of large scale exploitation of *Typha* by different subregional groups. Until proven otherwise, the discontinuous adoption of earth mound related cooking in the MDB, which is demonstrated in the currently available data, is a weakness for arguments related to continental models which posit a synchronous and continuous continental level trajectory of increasing socio-economic activity. Local differences potentially indicate a plethora of trajectories dictated by local circumstances (Hiscock and Sterelny 2023; Ulm 2013). In particular, the appearance of earth mounds signal a change in resource exploitation which involved significant changes in the way foraging labour resources were employed.

Calperum has provided evidence of the mobilisation of social and cultural innovation to address external challenge demonstrated by climatic and ecological change from at least 3800 cal BP. The persistence of a heat retainer based production system at Calperum into the late Holocene and the age variations in midden sites within the Calperum floodplain system demonstrate potential fluctuations in resource levels and the implementation of a broader diet through the increased exploitation of *Typha* root on a seasonal basis from this time. In addition, the demonstration of the implementation of technical and social innovation at family group and clan levels of organisation suggests a high level of cultural flexibility in dealing with external challenges. The possibility of a transition in food procurement practices linked to the diets of women and juveniles raises questions about the role and status of women in local groups. Their potential leadership in the adoption of a new method of procurement and the achievement of substantial productivity benefits suggests a significant role in socio-economic outcomes from the mid Holocene (if extrapolated from ethno-historical sources), in regions which adopted this technology.

The strong correlation to adverse climate change strongly suggests that behavioural change at Calperum was a function of external challenges and adaptation through innovation and socio-cultural reorganisation at subregional level from ~3800 cal BP. The dating evidence indicates that other regions in the MDB potentially experienced different conditions and influences that were expressed in different time frames. As previously noted, this finding reinforces Ulm's (2006:256) point about the importance of regional studies to identify both similarities and differences in the development of mid to late Holocene Aboriginal societies when investigating questions of intensification and changes in diet breadth.

The age data for mounds and middens obtained at Calperum shows a proliferation of dates after 1500 cal BP (Table 8.2 and Figures 7.15, 8.2) (Jones et al. 2022; Westell 2022, Westell et al. 2020). This is likely associated with improved environmental conditions and increased site formation. Alternatively, it may be due to taphonomic factors and the preservation of younger sites. However, the amelioration of climate (Gell et al. 2005) and the apparent increase in mound and midden formation suggest an increase in the seasonal exploitation of *Typha* and mussels after 1500 cal BP. The seasonal nature of *Typha* and the lack of longer-term storage capabilities suggests that potential short-term surpluses supported regional gatherings rather than population growth. Additional research is required to provide clarity to these issues particularly in respect to diet replacement/augmentation and productivity.

9.4 Limitations and future research

The results of the sediment and content analysis reported here have demonstrated the ability of such methods to provide data which can assist an understanding of mound formation processes and evidence of changes in the lifeways of Aboriginal peoples in the past. The opportunity exists to extend this study into mound precincts located in other subregions of the MDB as well as other locations such as the northern Adelaide plains, western Victoria and northern Australia. To my knowledge, there have been no such investigations of earth mound sediments from the many subregions of the MDB where they occur. These include the Macquarie Marshes, Murrumbidgee River, Darling River, Menindee Lakes and subregions of the Victorian and New South Wales borderlands. The latter area includes floodplain environments with an abundance (or high potential) of mound sites, including Swan Reach (Nyah), Pollack swamp, Wacol and Bahmah (see Table 2.2 for a list the locations where earth mound research has been conducted in Australia).

Future research could expand the focus on sediment analyses of earth mounds through the application of advanced techniques such as DNA analysis and sediment micromorphology. This was not pursued in this study due to a focus on other methods and to confine the study to a manageable scope. The study was also constrained to the excavation of six mounds in order to limit disturbance of the Aboriginal archaeology located on the floodplain at Calperum. Intensive studies involving excavation and dating would help to assist interpretations and solidify the chronology proposed here.

Further opportunities for future research on earth mounds include comparative studies of the factors and processes which gave rise to their appearance and development in two widely separated and climatically different regions at about the same time, namely northern and south-eastern Australia. Also, the generation of additional mound ages through the central Murray River region would be useful in determining the sequence of adoption of heat retainer technology and assist in clarifying regional socio-economic and cultural trajectories in the MDB. In particular, the uncertainty associated with the validity of radiocarbon ages based on charcoal from earth mounds in the MDB should be addressed as an early priority.

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Appendix One: Methods Assessed but not Included in the Calperum study.

Introduction

Prior to the availability of earth mound sediments from excavations at Calperum, sediments from earth mounds located near Weipa in northern Queensland were used to evaluate a number of methods not previously used in this context. SEM, FTIR, MS and plant microfossil analysis were selected for this purpose.

Methods

SEM

SEM images were obtained using a FEI Inspect 50 SEM by recording the secondary electron emission at an acceleration voltage of 5 kV and a working distances of 10 mm. Sediment samples were sputter coated with a thin silver layer to prevent charging. Elemental composition was determined via energy dispersive X-ray (EDX) spectroscopy using a 10 kV acceleration voltage.

The author acknowledges the leading participation of Dr Jason Gascooke of Flinders Microscopy and Microanalysis for the use of the facilities and scientific and technical assistance of Microscopy Australia. This input of the Australian National Fabrication Facility (ANFF) through the National Collaborative Research Infrastructure Strategy is also acknowledged.

FTIR

The FTIR instrument used was a Perkin-Elmer Spectrum 100 spectrometer with deuterated triglycine sulphate (DTGS) mid-Infrared detector with a Universal Attenuated Total Reflectance (ATR) accessory to analyse samples. Sediment samples were placed directly over a diamond crystal fitted within a circular mounting plate and measurements taken using 650-4000 cm^{1} (15 µm to 2.5 µm). Spectragryph optical spectroscopy software was used for the presentation of data. The author acknowledges and thanks Mr David Vincent, manager, Laboratory Services, College of Science and Engineering, Flinders for access and instruction on the Perkin-Elmer FTIR equipment.

Results of preliminary investigations

An examination of a sediment sample taken from Weipa mound WPEM33 did not demonstrate any identifiable evidence of plant tissue. Figure 1A.1 (left image) shows an SEM image of an organic structure with a width less than 1 micron, which was probably of microbiological origin and of indeterminate provenance. Figure 1A.1 (right image) shows the presence of mould mycelium in a sediment sample. The mycelium are likely to have propagated during storage from spores present within the sediment when sampled. The limited time available on the SEM equipment demonstrated nothing of interest other than the occasional presence of possible mould mycelium within the sediments. The difficulty of access, relatively high cost and the lack of a relevant result mitigated against pursuing this technique further.

The pilot FTIR study indicated potential to detect burnt termite mound sediments through a spectral signal difference between unfired termite mound material and mound sediments between 1000 to 1100 and 3250 to 3750 wavenumbers (cm^{-1}) (Figure 1A.2). Unfired termite mound material achieved an absorbance reading above 0.35. at ~1000 (wave no./cm).The reading for spits 2–4 at ~1000 clustered around an absorbance of 0.175 and spit one at an absorbance of 0.11. However, the result did not show sufficient resolution to indicate differences in burning intensity between excavation spits with depth (Figure 1A.2). In contrast the analyses conducted with the Bartington MS3 instrument using the MS2B sensor did demonstrate the ability to provide this resolution (Figure 1A.3) The plot of low frequency (LF) and high frequency (HF) for Weipa mound 33 in Figure 1A.3, shows higher resolution of the decrease in MS with depth and consequently the Bartington system was selected for use in preference to the Perkin-Elmer Spectrum 100 spectrometer.

The pilot results for the phytolith, pollen and starch studies on Weipa mound sediments were promising (see Appendix Two), providing useful insights into local ecology and resource exploitation at the time of sediment formation (Beck 2006:296–310; Brooks and Johannes 1990). Due to the results obtained, MS (Figure 1A.3) and plant microfossil analysis were adopted for further work at Calperum, however, due to the lack of appropriate facilities at Flinders University, the latter analysis was again outsourced to the Paleo Institute in Golden, Colorado, USA.

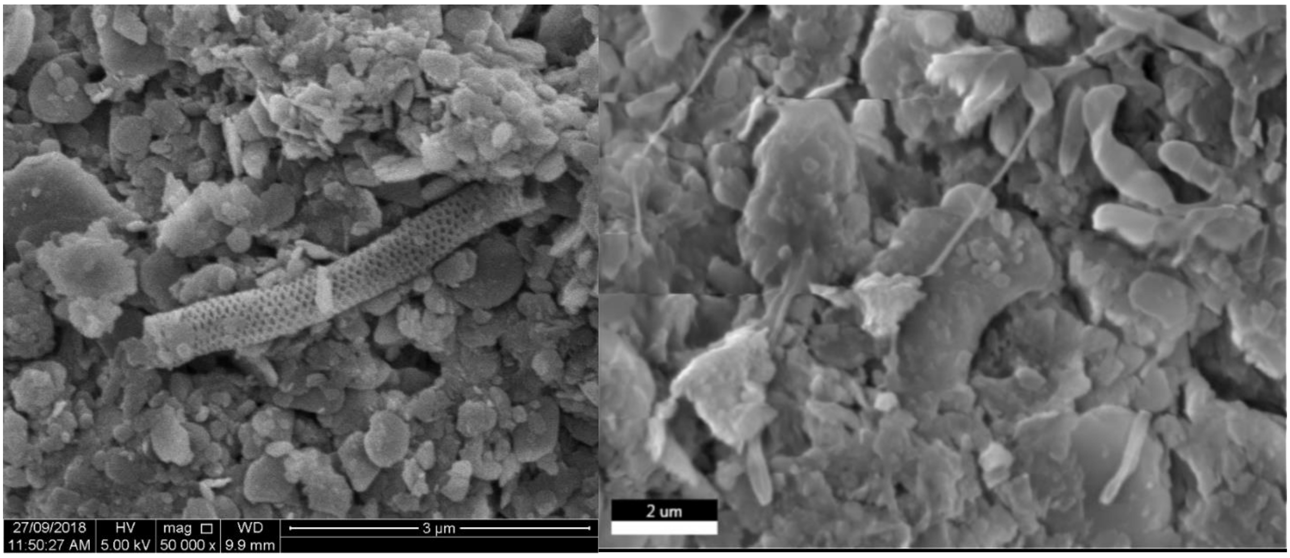

Figure 1A.1: A SEM image (left) of a potential organic structure of indeterminate provenance, with a diameter less than 1 micron from Weipa mound WPEM33. Right is a SEM image of sediment from Weipa earth mound WPEM33 showing mould mycelium in the upper right corner.

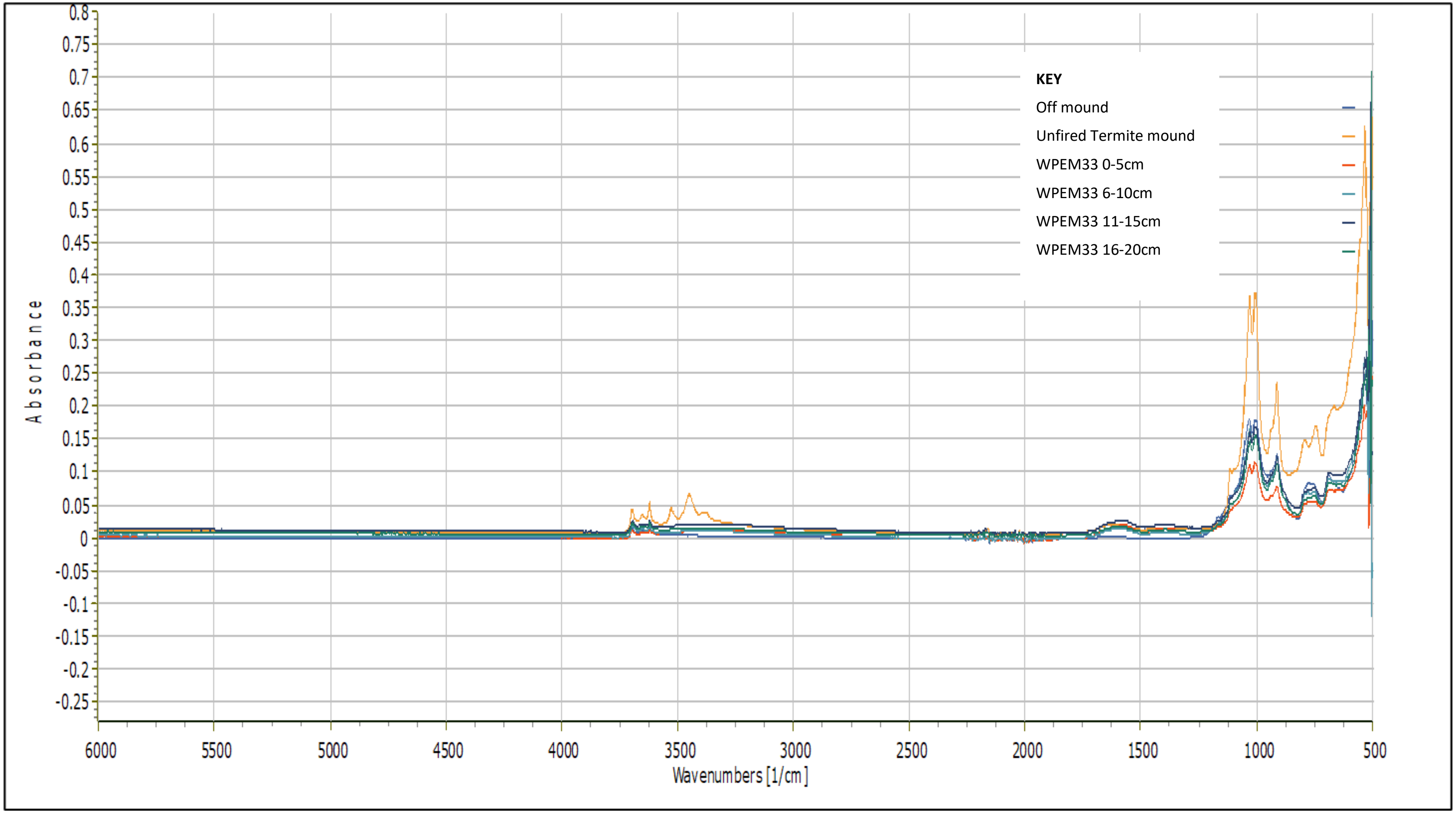

Figure 1A.2: FTIR spectra for Weipa earth mound 33, colour code order top to bottom indicates off mound sediment, unfired termite mound material and spits 1 to 4.

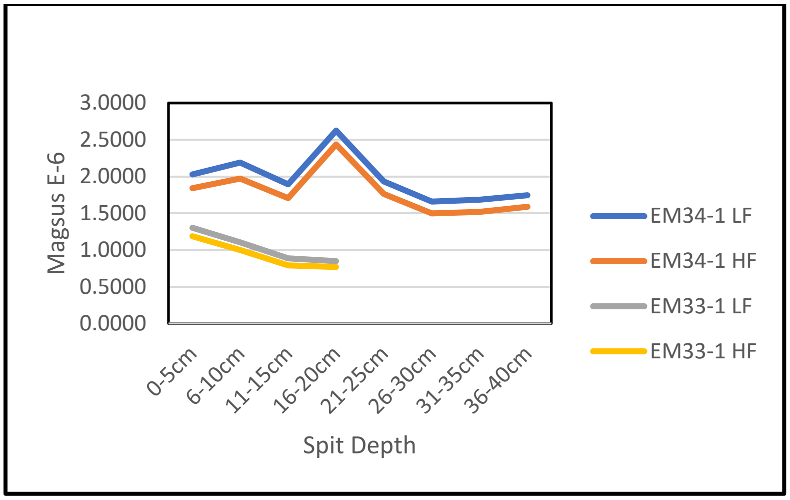

Figure 1A.3: Plots of low (LF) and high frequency (HF) MS values for Weipa mounds 33 and 34.

Appendix Two: Plant Microfossil Reports

1. Weipa Pilot Study

POLLEN, PHYTOLITH, AND STARCH ANALYSES ON SEDIMENT SAMPLES FROM WATHAYN, NORTH QUEENSLAND, AUSTRALIA

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INTRODUCTION

Earth Mounds 33 and 34 are located in the Wathayn locality on the Weipa Peninsula of northern Cape York in Queensland, Australia. Evidence suggests that occupation of the earth mounds at Wathayn began after 2000 BP, with the height of occupation occurring between 500and 100 BP. Use of the earth mounds on the Weipa Peninsula continued well after European settlement, with evidence for Aboriginal adoption of new technologies suggestive of occupation into the modern era (Stevenson et al. 2015:28). The Wathayn traditional owners continue to use the same cooking methods as those associated with the earth mounds (Foghlú 2017:62). The appearance and gradual predominance of earth mounds on the landscape could signal new diets adopted in the mid-Holocene (Robert Jones, personal communication, 18 June 2019;Foghlú 2017:66). Therefore, pollen, phytolith, and starch analyses of sediment from Earth Mounds 33 and 34 at Wathayn were sought to investigate whether or not components of diet could be detected, and, through the resultant data, specific questions about changing environment, demographics, and subsistence could be answered.

METHODS

Pollen

Sediments often present unique challenges for pollen preservation and recovery, meaning that larger samples are required for land sediments than for pollen recovery from lakesediments or peat bogs. A chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for recovering pollen grains from sediments. Thisparticular process was developed for extracting pollen from soils where the ratio of pollen to inorganic material is relatively low. It is important to recognize that it is not the repetition of specific and individual steps in the laboratory, but rather mastery of the concepts of extraction and how the desired result is best achieved, given different sediment matrices, that results in successful recovery of pollen for analysis.

Hydrochloric acid (10%) was used to remove calcium carbonates present in the sediment samples, after which, they were screened through 250-micron mesh. Multiple waterrinses were utilized until neutral employ Stoke’s Law for settling time. After settling the supernatant was poured off. A small quantity of sodium hexametaphosphate was mixed into each sample to suspend clay-sized particles prior to filling the beakers with water. Again, multiple rinses employing Stoke’s Law and decanting facilitated clay removal. Treatment with sodium hexametaphosphate was repeated, as necessary, to remove clay. This process was repeated with ethylenediaminetetraacetic acid (EDTA), which removes clay, soluble organics,and iron. Finally, the samples were freeze-dried under vacuum.

Once dry, the samples were mixed with sodium polytungstate (SPT), at a 1.8 g/ml density, and centrifuged to separate the organic material including pollen and starch, which floats, from the inorganic remains and silica, which do not float. The supernatant containingpollen and organic remains was decanted and retained. The sodium polytungstate process was repeated to

recover all of the organics. Once the organics were recovered, the accumulated supernatant was centrifuged at 1,500 rpm for 10 minutes to allow small-sized silica to be separated from the organics. This supernatant was decanted into a 50-ml conical tube and diluted with reverse osmosis deionized (RODI) water and centrifuged at 3,000 rpm to concentrate the organic fraction in the bottom of the tube. This pollen-rich organic fraction wasrinsed, then all samples received a short (25 minute) treatment in hot hydrofluoric acid to remove remaining inorganic particles. The samples were acetylated twice for 10 minutes eachto remove extraneous organic matter. The samples were rinsed with RODI water to neutral.
Following this, a few drops of potassium hydroxide (KOH) were added to each sample, which was then stained lightly with safranin. Due to the presence of large quantities of minute organic debris, the samples were centrifuged at high speeds for short intervals to remove this debris for better viewing.

A light microscope was used to count pollen at a magnification of 400x. Pollen preservation in these samples varied from very good to poor. An extensive comparative reference housed at PaleoResearch Institute aided pollen identification to the family, genus,and species level, where possible. The Australasian Pollen and Spore Atlas (Australian National University 2007) also provided a useful database of comparative images, morphological descriptions, and geographic distribution data.

Pollen aggregates were recorded during pollen identification. Aggregates are clumps ofa single type of pollen and may be interpreted to represent either pollen dispersal over short distances or the introduction of portions of the plant represented into an archaeological setting. The aggregates were included in the pollen counts as single grains, as is customary. An "A" next to the pollen frequency on the percentage pollen diagram notes the presence of aggregates. The percentage pollen diagram was produced using Tilia Version 2.1.1. Total pollen concentrations were calculated in Tilia using the quantity of sample processed in cubic centimeters (cc), the quantity of exotics (spores) added to the sample, the quantity of exotics counted, and the total pollen counted and expressed as pollen per cc of sediment.

"Indeterminate" pollen includes pollen grains that are folded, mutilated, or otherwise distorted beyond recognition. These grains were included in the total pollen count since they are part of the pollen record. The microscopic charcoal frequency registers the relationship between pollen and charcoal. The total number of microscopic charcoal fragments was dividedby the pollen sum, resulting in a charcoal frequency that reflects the quantity of microscopic charcoal fragments observed, normalized per 100 pollen grains.

Our pollen and phytolith extraction method retains starch granules when they are present. Since starch analysis was requested for these samples, not only would starches be recorded as part of the pollen count, an additional search for starches was also conducted. Starchgranules are a plant's mechanism for storing carbohydrates. Starches are found in numerous seeds, as well as in starchy roots and tubers. The primary categories of starches include the following: with or without visible hila, hilum centric or eccentric, hila patterns (dot, cracked, elongated), and shape of starch (angular, ellipse, circular, or lenticular). Some of these starchcategories are typical of specific plants, while others are more common and tend to occur in many different types of plants.

Phytolith and Starch

Extraction to recover both phytoliths and starch grains from the sediment samples is based primarily on our phytolith extraction method. First, 15 ml of sediment from each sample was placed in a beaker with bleach. After being agitated it was covered and allowed to stand overnight. The next day the beakers containing samples were filled with water and allowed to settle by gravity for one and one-half hours, after which the supernatant was poured off. This rinse was repeated four times to remove the bleach. A small quantity (10 ml) of dilute (10%) potassium hydroxide (KOH) was added to each sample after the fourth rinse, allowed to sit for two minutes, and then the beakers were filled with water for another series of four rinses on the same schedule. Once these steps were complete, 15 ml of a 5% solution of sodium hexametaphosphate was mixed into each sample to suspend clay-sized particles. Again, the beakers were filled with water and allowed to settle by gravity for two hours, after which the clay-sized particles that were still in suspension were decanted. This was repeated four more times. The samples then were freeze-dried using a vacuum system, which freezes out all moisture at -107 C and < 10 millitorr. The dried samples were mixed with sodium polytungstate (SPT, density 2.1 g/ml) and centrifuged to separate the phytolith and starch grainfraction, which will float, from most of the inorganic silica fraction, which will not. The light fraction of each sample was retained and rinsed to remove the heavy liquid. The phytolith- andstarch-rich fraction of each sample was rinsed in alcohol to remove any remaining water.
Microscope slides were made by putting a drop of sample on a slide, allowing it to dry, then mixing with optical immersion oil prior to covering with a cover slip for counting with a light microscope at a magnification of 500x. A percentage and/or frequency diagram was produced using Tilia 2.0 and TGView 2.0.2.

DISCUSSION

Earth Mounds 33 and 34 at Wathayn are situated just north of the estuarine limit above the west-flowing Embley River. A bauxite mining operation lies upon the plateau to the north within 1.25 km of the mounds. Nearby, several small, freshwater drainages run southwest down the plateau and into the estuary. The surrounding vegetation represents various wetland environments (Robert Jones, personal communication, 18 June 2019). The saltwater wetlandsof the estuary are defined by the mangrove ecosystem, including (in different quantities and proportions) *Rhizophora stylosa* (spotted mangrove) and *Ceriops tagal* (spurred mangrove). Along freshwater courses, *Melaleuca* spp. (paperbarks) and *Lophostemon suaveolens* (swamp mahogany) are prevalent, while a variety of *Acacia* spp. and beach scrub/vine forest (e. g. *Dysoxylum oppositifolium* (opposite-leaf mahogany), *Canarium australianum* (mango bark), *Buchanania arborescens* (little gooseberry), *Ganophyllum falcatum* (scaly ash)) grow along the coast. Open forest dominated by *Eucalyptus tetrodonta* (Darwin stringybark), *Corymbia* spp.

(bloodwood), and *Erythrophleum chlorostachys* (Cooktown ironwood) is common on the plateau (Stevenson, et al. 2015:16)

A recent palynological analysis of sediment cores from the Big Willum Swamp (Waandriipayn), located upon the coastal plain ca. 6 km north of Earth Mounds 33 and 34, presents the first paleoenvironmental record for the Weipa region (Stevenson, et al. 2015:18).Based upon the pollen record, Eucalypteae (eucalyptus tribe)-dominated open forest regime persists at Big Willum Swamp for the majority of the Holocene. Despite such predominance, sediment deposition and subtle shifts in the pollen record of the understory provide insights on environmental changes from as early as 8000 BP to present day. Notably, sedimentation at the swamp indicates a gradual shift to a moister, and stable environment from 2200 cal. BP onward (Stevenson, et al. 2015:27). Although charcoal is present throughout the cores, a significant peak in charcoal quantity may represent increased fire activity ca. 1000 cal. BP. From 600–400 cal. BP, sedimentation along the swamp periphery, the dominance of *Corymbia* spp., and the presence of *Leptospermum* spp. (tea tree) pollen in the record suggest a wetter environment with greater seasonal inundation.

Stevenson et al. (2015:28) discuss the importance of the paleoenvironmental dataset from Big Willum Swamp to underscore broader scholarship on regional cultural developmentsover time. From 2700–2200 cal. BP, the environment was particularly dry and warm. Concurrent with this dry spell, the greatest concentrations of shell mounds at Wathayn appear. However, *Tegillarca granosa* (syn. *Anadara granosa*; blood cockle) shell beds “may have been impacted through increased siltation and freshwater inputs” as the environment became wetter, reducing the primary food resource on the Weipa peninsula (Stevenson, et al. 2015:28). Stevenson et al. (2015:28) contend that the impacts on and gradual reduction of *Tegillarca granosa* yields may have played a key role in the appearance of the earth mounds beginning around 2000 years ago. Aboriginal subsistence, driven by climate change from 2200 cal. BP, began to incorporate inland resources in greater numbers, as indicated by the appearance of the earth mounds and, in 1000 cal. BP, increased fire activity. The significantly wetter period from 600–400 cal. BP onward corresponds with a substantial upturn in earth mound occupation around 500 cal. BP, which could potentially demonstrate that Wathayn traditional owners directly adapted subsistence, not to mention ritual and social organization, in reaction to climatic factors.

Two sediment samples from Earth Mounds 33 and 34 were examined for pollen, phytoliths, and starches (Table 1) to determine the quality of these proxy records in this particular location. Additional samples are available for future analysis should the preservationof materials in these records be deemed sufficient to contribute to greater understanding of human use of the area. Both sediment samples were recovered from the center of their respective earth mounds. Sample WPEM33 was retrieved from 11–20 cmbs and represents acombination of Levels 3 and 4 in Earth Mound 33. Pollen analysis revealed unusually high concentration values for archaeological pollen, and several taxa of likely economic significancewere identified. Microcharcoal concentrations were high for both of the samples analyzed, which likely represent discard of ashy deposits.

Pollen from Earth Mound 33 had surprisingly high concentration values (approximately 184,000 grains/gram of sediment) (Figure 1). Poaceae (grass family) pollen was the most common pollen type (Table 2) and made up approximately 50% of the pollen counts for this sample. Many of the grass pollen grains identified were exceptionally large. This pollen may be an environmental or disturbance indicator, but since 50% is significantly higher than the percentages of grass pollen identified in the environmental record by Stevenson et al. (2015) (<20% for all samples), it is probable that some of this pollen is indicative of economic grass seed use. The most common arboreal pollen was from the family Myrtaceae, which includes Eucalyptus and Syzygium (Java plum). Pollen from the family Sapotaceae, observed in both this sample and that from Earth Mound 34, may be associated with edible fruit, often produced by trees and shrubs from this family.

The phytolith signature for Earth Mound Sample 33 was dominated by elongate smooth phytoliths typical of grasses and sedges (Figure 2). When Cyperaceae (sedge family) short cellphytoliths are present it is reasonable to assume these forms may represent plants in both families. A few Cyperaceae phytoliths were observed in this sample. When they are not it is more likely these forms represent only grasses. The few elongate spiny forms are similar in their distribution. Bulliforms also are common in both grasses and sedges, as they represent cells that control leaf rolling in response to drought. One bulliform from this sample exhibited peaks, suggesting it is identifiable at a more specific level. It is not similar to rice reference samples in our collection. Dendriforms are produced in the glumes surrounding seeds of festucoid or cool season grasses. Only a few were observed. Trichomes, which are silicified plant hairs typically produced in grasses and sedges, were present, but not particularly abundant. Interstomatal cells are located between leaf stomata and are common in grasses.

Grass short cells representing festucoid (cool season), chloridoid (short), and panicoid (tall) grasses include rondel, saddle, bilobate, and polylobate forms. Bilobates, representing tallgrasses that prefer humid conditions, were the most abundant. Recovery of grass short cells indicates good preservation conditions.

Dicotyledenous plants (dicots) are represented by a few phytoliths of different morphologies. None were considered diagnostic. Spherical phytoliths commonly associatedwith woody tissues were observed but could not be identified to a more specific level.

Spherasters, which represent freshwater sponges were present, but not abundant. In addition, freshwater sponge spicules were noted. Phytoliths were abundant and generally wellpreserved, although some of the larger phytoliths such as bulliforms exhibited pitting typical of partial dissolution.

Starches were observed primarily in the phytolith extractions. Two morphotypes that wetracked do not appear to be starches but did present visible extinction crosses under cross- polar illumination. Their pale gold to brown color and slightly diffuse surface suggests they are not starches. Another form, described as “sunburst with rind” is a flat, circular object with a border, looking very similar to a bordered pit. The exception is the presence of lines radiating from the center in a sunburst pattern. Bordered pits often occur still embedded in plant tissue, lining up next to one another. Although both of these forms were abundant, we consider neither to represent starches. Uric acid spherulites were observed in both samples but were not counted.

Earth Mound Sample 33 contained an abundance of starch imitators described as granular bodies and “sunburst with rind” bodies, both of which exhibited an extinction cross under cross-polar illumination. In addition, this sample yielded two starches on the slide. One was identified as *Dioscorea*-type (Table 3), while the other was a simple, spherical starch with acentric hilum. Recovery of *Dioscorea*-type starch suggests the presence of yams. The second starch is a common morphology in grass seeds, making it of less interest economically.

Sample WPEM34 represents Level 7 at a depth of 31–35 cmbs in Earth Mound 34. Pollen analysis revealed a lower total pollen concentration value than that associated with the sample from Earth Mound 33, (approximately 20,000 grains/gram of sediment). This sample exhibited a wider variety of taxa, including those with potential economic significance. The small quantity of Araucariaceae family pollen recorded suggests local growth of conifer trees that comprise an ancient family of trees. Araucarians were most abundant during the Jurassic and Cretaceous periods. This family includes species that are useful for timber, resin, and produce edible nuts. This sample also included multiple pollen grains (including aggregates) of *Buchanania* pollen. *Buchanania obovata* is commonly known as green plum or wild mango and produces edible fruit. The presence of pollen aggregates from this taxon indicates that *Buchanania* was either growing on site, or that portions of the plant were harvested and broughtto the site. Pollen that appeared to be from the genus *Prunus* most likely represents *Prunus turnerana*, a native species that produces edible fruits. An aggregate of pollen from this taxon potentially indicates the presence of the plants nearby or its economic use.

The phytolith signature for Earth Mound 34 was very similar to that in WPEM33. Differences, although minor, include recovery of a single, small cross-shaped body typical of Panicoid or tall grasses. No bulliform peaked phytoliths, Cyperaceae, or interstomatal cell phytoliths were observed. Dicot phytoliths were present and included parallelepiped and tracheary elements rather than bulky forms. Spherical phytoliths typical of woody tissues also were observed. This sample displayed a few pennate diatoms, as well as spherasters.

Earth Mound 34 starch analysis yielded a greater variety of starches and fewer granular bodies and sunburst forms with a rind. Starches have been identified as cf. (meaning comparable to) Araceae, *Dioscorea*-type, lenticular, ovate with an eccentric hilum, spherical with a centric hilum, and small spheroidal with a centric hilum. Spherical or spheroidal starches with centric hila are typical of, but not restricted to, grass seeds. They also occur in seeds of many other plants. Unless the starch is rotated during identification ovoid starches may presentas spherical when viewed from the polar, rather than an equatorial view. Lenticular starches are common in festucoid or cool season grass seeds. Finally, the Araceae starch might reflect *Alocasia*, although we do not have that starch in our reference collection. It did match an imagein Torrence and

Barton (2006).

SUMMARY AND CONCLUSIONS

Combined pollen, phytolith, and starch analysis of two samples representing Earth Mounds 33 and 34 yielded a diverse pollen record in agreement with Stevenson et al.'s (2015) published record. The preservation was sufficient to recommend further pollen analysis of earth mounds. Specifically, the high pollen concentration values and presence of pollen aggregates associated with taxa of potential economic importance (including fruit-producing plants), is a strong indication that future investigations would have excellent potential to contribute to archaeological understandings of economic plant use in this area. Due to the factthat we have only a single sample from each mound no interpretations of climate or environmental history were attempted. Several pollen taxa indicate economic plants in these earth mound samples, indicating that further pollen analysis is likely to recover evidence of economic activity tied to these mounds.

The phytolith record was well preserved, which is attested by recovery of grass short cells. Bilobates were the most abundant grass short cell, indicating local growth of tall grasses. Numerous spherical phytoliths typical of the non-descript phytoliths common in woody tissue were noted. Although they cannot be identified even to family, they indicate forest cover or possibly use of wood in the earth mounds. That woody signature is better defined by the pollen record. Presence of a peaked bulliform should be examined further. Although this morphotype does not match our reference for rice, it is possible it represents a different variety of rice or grass grown for economic purpose.

Starch recovery in both samples suggests there is a starch record in each of the earthmounds, suggesting that future starch analysis will help to better understand this portion of the economic record. Specifically, starches suggest the presence of a broad-leaved, rhizomatous or tuberous perennial in the arum family, yams, and grass seeds.

TABLE 1

PROVENIENCE DATA FOR SEDIMENT SAMPLES FROM WATHAYN, NORTH QUEENSLAND, AUSTRALIA

Sample No.	Mound	Unit	Level	Depth (cmbs)	Provenience / Description	Analysis
WPEM33	33	SU1	3–4	11–20	Feature fill from the center of earth moundabove base of feature	Pollen Phytolith Starch
WPEM34	34	SU1	7	31–35	Feature fill from the center of earth moundabove base of feature	Pollen Phytolith Starch

TABLE 2
Pollen types observed in samples from Wathayn, North Queensland, Australia

Scientific Name	Common Name
ARBOREAL POLLEN:	
Anacardiaceae:	Sumac family
Buchanania-type	Green plum, Wild mango
Araucariaceae	Araucarians
Myrtaceae	Eucalyptus family
Sapotaceae	Manilkara family
NON-ARBOREAL POLLEN:	
Amaranthaceae	Amaranth family (now includes Chenopodiaceae,these two families were combined based on genetic testing and the pollen category “Cheno- ams”)
Asteraceae:	Sunflower family
Artemisia-type	Sagebrush
Low-spine	Includes Ragweed, Cocklebur, Sumpweed
High-spine	Includes Aster, Rabbitbrush, Snakeweed,Sunflower, etc.
Liguliflorae	Chicory tribe, includes Dandelion and Chicory
Bertya	Bertya
Cyperaceae	Sedge family
Epacridaceae	Australian heath family
Epacris	Heath
Fabaceae:	Bean or Legume family
Carmichaelia	New Zealand broom
Zornia	Zornia
Gunnera	Gunnera
Haloragaceae	Watermilfoil family
Melicope	Melicope
Poaceae	Grass family

TABLE 2 (Continued)

Scientific Name	Common Name
Rosaceae:	Rose family
Prunus	Chokecherry, Cherry, Plum, etc.
Solanaceae	Potato/Tomato family
Indeterminate	Too badly deteriorated to identify
STARCHES:	
cf. Araceae	Arum family
Dioscorea-type	Yam
Lenticular starch	Typical of starches produced by grass seeds suchas those from wheat grass (*Agropyron*), ryegrass (*Elymus*), or barley grass (*Hordeum*)
Spherical, centric	Typical of starches produced by grass seeds
Spheroidal, centric small	Typical of starches produced by grass seeds
SPORES:	
Reticulate spore	Fern
ALGAE:	
Algal spore fenestrate	Algal spore
OTHER:	
Microscopic charcoal	Microscopic charcoal fragments
Total pollen concentration	Quantity of pollen per cubic centimeter (cc) of sediment

TABLE 3
Starch types observed in samples from Wathayn, North Queensland, Australia

Starches:	Sample 33	Sample 34
cf. Araceae		1
Dioscorea-type	1	3
Lenticular		3
Spherical, centric	1	1
Spheroidal, centric small		1
Granular bodies (not starch)	81	7
Sunburst with rind (not starch)	102	30
Uric acid spherulites (not starch)	X	X

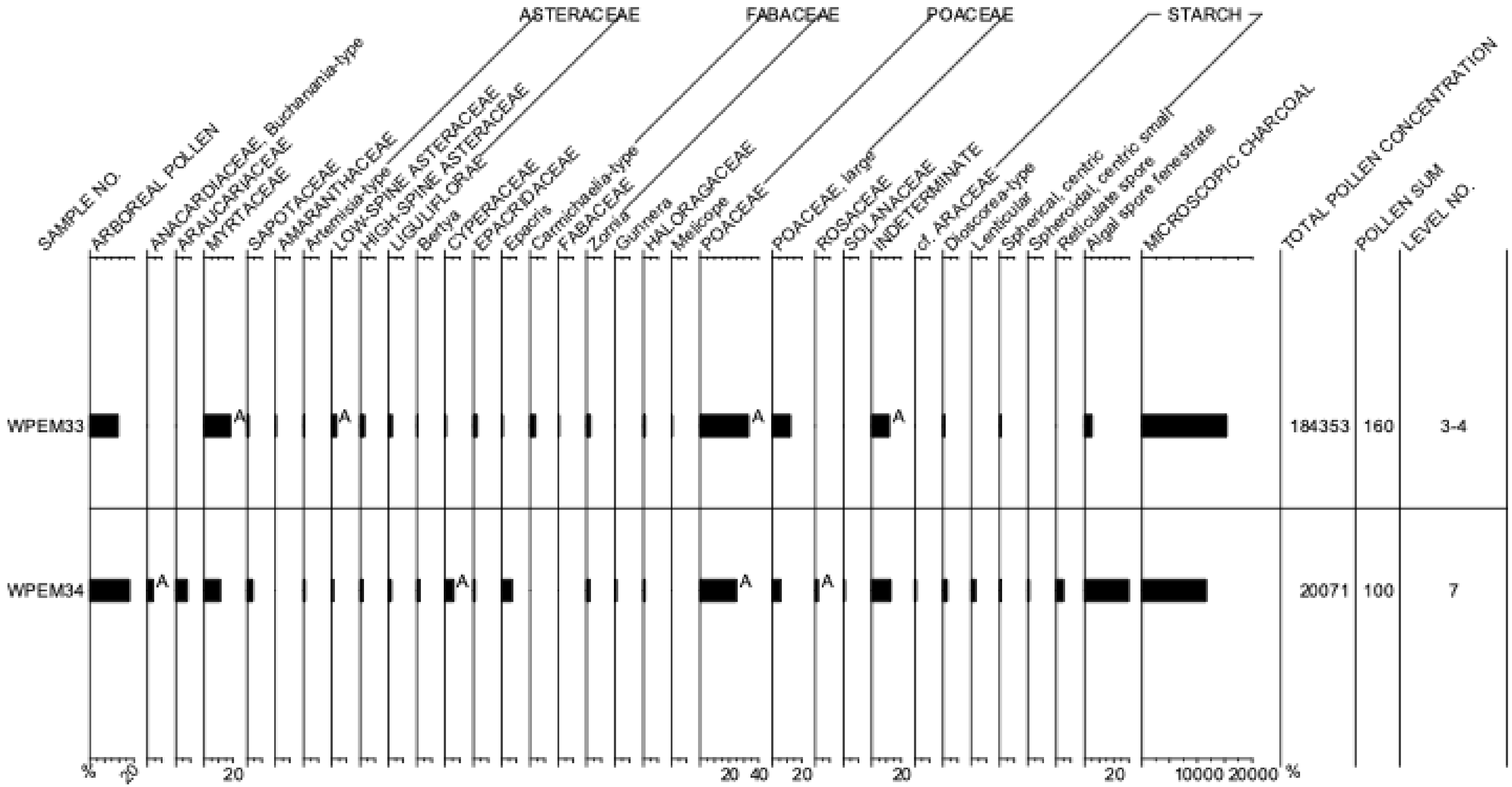

Figure 1: Pollen diagram for samples from Wathayn, North Queensland, Australia.

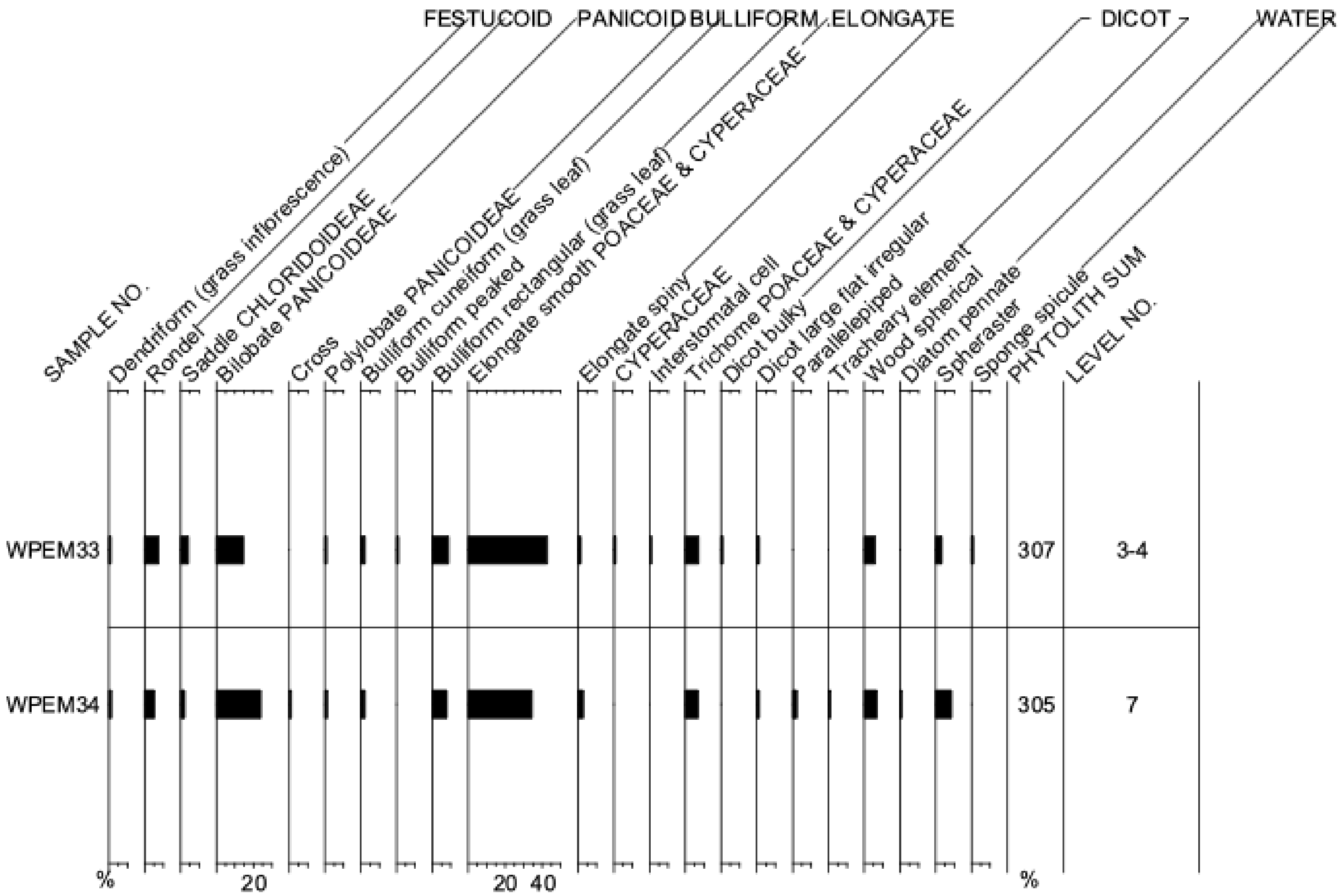

Figure 2: Phytolith diagram for samples from Wathayn, North Queensland, Australia.

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2. Calperum Microfossil Study

POLLEN, PHYTOLITH AND STARCH ANALYSES OF SAMPLES FROM CALPERUMFLOODPLAIN, RENMARK, SOUTH AUSTRALIA

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INTRODUCTION

Mid- to late Holocene Australian Indigenous earth mounds located in northern Cape York and the Murray Darling Basin were examined archaeologically. Broad spectrum diets (BSD) are hypothesised to have been important as a transition strategy during the terminal phase of the last glaciation. This strategy is thought to have allowed occupation of previously marginal regions and/or innovative exploitation of low trophic resources such as toxic nuts and grass seeds that require extensive processing to be edible (Ferrier and Cosgrove 2012; Haberle and David 2004; and Hiscock 2008). Fullagar and Field (1997) provide a discussion of the antiquity of seed grinding in this context. Pollen, phytolith, and starch analyses of six billabong sediment samples from the Calperum Floodplain address the research question concerning the role and significance of earth mounds within regional Aboriginal coastal/riverine/wetland practices during the mid- to late Holocene. Examining these samples isexpected to provide information that may address the purported introduction of broad-spectrum diets at this time.

METHODS

Pollen

Sediments often present unique challenges for pollen preservation and recovery, meaning that larger samples are required for land sediments than for pollen recovery from lakesediments or peat bogs. A chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for recovering pollen grains from sediments. Thisparticular process was developed for extracting pollen from soils where the ratio of pollen to inorganic material is relatively low. It is important to recognize that it is not the repetition of specific and individual steps in the laboratory, but rather mastery of the concepts of extraction and how the desired result is best achieved, given different sediment matrices, that results in successful recovery of pollen for analysis.

Hydrochloric acid (10%) was used to assess and remove any calcium carbonates present in the sediment samples. No reaction was observed. Next, samples were screened through 250-micron mesh. Multiple water rinses neutralized the solution employing Stoke’s Lawfor settling time. A small quantity of sodium hexametaphosphate was added to the first rinse of the day to suspend clay-sized particles prior to additional rinsing using Stoke’s Law. This process was repeated with ethylenediaminetetraacetic acid (EDTA), which removes clay, soluble organics, and iron. Finally, the samples were freeze-dried under vacuum.

Once dry, the samples were mixed with sodium polytungstate (SPT), at a density of 1.8g/ml, and centrifuged to separate the organic material including pollen and starch, which floats,from the inorganic remains and silica, which do not float. The light fraction was recovered, and the process was repeated, as many times as necessary. This pollen-rich organic fraction was rinsed, then all samples received a short (25 minute) treatment in hot hydrofluoric acid to remove remaining inorganic particles. The samples were acetylated for 10 minutes to remove extraneous organic matter. The samples were rinsed with RODI water to neutral. Following this, a few drops of potassium hydroxide (KOH) were added to each sample, which were then stained lightly with safranin. Due to the presence of large quantities of minute organic debris, the samples were centrifuged at high speeds for short intervals to remove this debris for better viewing.

A light microscope was used to count pollen at a magnification of 500x. Pollen preservation in these samples varied from good to poor. An extensive comparative reference housed at PaleoResearch Institute aided pollen identification to the family, genus, and specieslevel, where possible.

Pollen aggregates were recorded during pollen identification. Aggregates are clumps ofa single type of pollen and may be interpreted to represent either pollen dispersal over short distances or the introduction of portions of the plant represented into an archaeological setting. The aggregates were included in the pollen counts as single grains, as is customary. An “A” next to the pollen frequency on the percentage pollen diagram notes the presence of aggregates. The percentage pollen diagram was produced using Tilia Version 2.1.1. Total pollen concentrations were calculated in Tilia using the quantity of sample processed in cubic centimeters (cc), the quantity of exotics (spores) added to the sample, the quantity of exotics counted, and the total pollen counted and expressed as pollen per cc of sediment.

“Indeterminate” pollen includes pollen grains that are folded, mutilated, or otherwise distorted beyond recognition. These grains were included in the total pollen count since they are part of the pollen record. The microscopic charcoal frequency registers the relationship between pollen and charcoal. The total number of microscopic charcoal fragments was dividedby the pollen sum, resulting in a charcoal frequency that reflects the quantity of microscopic charcoal fragments observed, normalized per 100 pollen grains.

Our pollen and phytolith extraction method retains starch granules when they are present. Since starch analysis was requested for these samples, not only would starches be recorded as part of the pollen count, but an additional search for starches was also conducted. Starch granules are a plant's mechanism for storing carbohydrates. Starches are found in numerous seeds, as well as in starchy roots and tubers. The primary categories of starches include the following: with or without visible hila, hilum centric or eccentric, hila patterns (dot, cracked, elongated), and shape of starch (angular, ellipse, circular, or lenticular). Some of these starch categories are typical of specific plants, while others are more common and tend to occur in many different types of plants.

Phytolith and Starch from Sediment

Extraction to recover both phytoliths and starch grains from the sediment samples is based primarily on our heavy liquid technique for pollen extraction. First, 15 ml of sediment from each sample was placed in a beaker with bleach, an oxidant, then allowed to sit overnight. The next day the beakers containing samples were filled with water and allowed to settle by gravity (using Stokes Law) for one and one-half hours, after which the supernatant was poured off. This rinse was repeated four times to remove the bleach or oxidizing agent. The next step in organic removal was to introduce a small quantity of dilute potassium hydroxide (KOH), whichwas not allowed to sit long because it may damage the silica bodies. Additional rinses removeddissolved organics. Clays were removed using sodium hexametaphosphate and a repetition of the Stokes law settling. The samples then were freeze-dried using a vacuum system, then mixed with sodium polytungstate (SPT, density 2.1 g/ml) and centrifuged to separate the phytolith and starch grain fraction, which will float, from most of the inorganic silica fraction, which will not. The light fraction of each sample was retained and rinsed to remove the heavyliquid. The phytolith- and starch-rich fraction of each sample was rinsed in alcohol to remove any remaining water. Microscope slides were made by putting a drop of sample on a slide, allowing it to dry, then mixing with optical immersion oil prior to covering with a cover slip for counting with a light microscope at a magnification of 500x. A percentage and/or frequency diagram was produced using Tilia 2.0 and TGView 2.1.1.

Phytolith review

Phytoliths are silica bodies produced by plants when soluble silica in the ground water absorbed by the roots is carried up the plant's vascular system. Evaporation and metabolism ofthis water result in precipitation of the silica in and around the cellular walls. Opal phytoliths, which are distinct and decay-resistant plant remains, are deposited in the soil as the plant or plant parts die and break down. However, they are subject to mechanical breakage, erosion, and deterioration in high pH soils. Usually, phytoliths are introduced directly into the soils in which the plants decay. Phytolith transportation occurs primarily through animal consumption, human plant gathering, or wind, water, or ice soil erosion or transportation. Phytoliths producedin roots/tubers deteriorate at the level of those roots/tubers and are not represented on the growing surface. Therefore, roots/tubers phytolith recovery from stratigraphic sediments does not necessarily represent vegetation coeval with that represented by phytoliths produced in leaves or other above ground vegetative parts.

The three major types of grass short-cell phytoliths include festucoid, chloridoid, and panicoid. Smooth elongate phytoliths provide no aid interpreting either paleoenvironmental conditions or the subsistence record, because all grasses, various other monocot plants, and several dicots produce them. Phytoliths tabulated to represent "total phytoliths" include the grass short-cells, bulliform, trichome, elongate, and dicot forms. All other silica and non-silica body recovery frequencies are calculated by dividing the number of each type recovered by the"total phytoliths."

The festucoid class of phytoliths is ascribed primarily to the subfamily Pooideae and occurs most abundantly in cool, moist climates. They grow well in shady areas and during the cooler spring and fall months. They are the first grasses to “green up” in the spring, going dormant in the summer, then growing again in the fall. Brown (1984) notes that festucoid phytoliths are produced in small quantity by nearly all grasses (mostly rondel-type phytoliths, which exhibit an approximately circular shape). Therefore, while these typical phytolith forms are produced by the subfamily Pooideae, they are not exclusive to this subfamily. Trapeziformphytoliths are tabular and may be thin or thick. Their outer margins may be smooth, slightly spiny, or sinuate.

Warm season or summer grasses are divided into the group that thrives in dry conditions (chloridoid) and those that grow best in humid conditions (panicoid) or that grow along sources of water. Chloridoid saddle phytoliths are produced by the subfamily Chloridoideae, a warm-season grass that grows in arid to semi-arid areas and requires less available soil moisture (Gould and Shaw 1983:120). They thrive in hot, dry conditions of summer. Twiss (1987:181) notes that some members of the subfamily Chloridoideae also produce both bilobate (panicoid) and festucoid phytoliths. Also, saddles may be produced in non-chloridoid grasses. Bilobates and polylobates (lobates) are produced mainly by panicoid (tall) grasses, although a few festucoid grasses also produce these forms. Panicoid or tall grasses prefer the warmth of summer and thrive in humid conditions or grow next to water suchas creeks, rivers, and lakes. More than 97% of the native U.S. grass species (1,026 or 1,053) are divided equally among three subfamilies: Pooideae, Chloridoideae, and Panicoideae (Gouldand Shaw 1983:110).

Bulliform phytoliths are produced in grass leaf cells that control leaf rolling in responseto drought. These cells often silicify under wet or moist conditions and increase in abundanceas the grass leaves age. Trichomes represent silicified hairs, which may occur on the stems, leaves, and the glumes or bran surrounding grass seeds.

Terms applied to phytoliths in this study use the International Code for Phytolith Nomenclature (ICPN) (Madella et al. 2005). Phytolith reference samples prepared and curatedat PaleoResearch Institute were consulted when identifying phytoliths recovered in this study.

Other Siliceous Microfossils

Diatoms and/or sponge spicules were noted. Pennate diatoms are cosmopolitan, occurring in many sediments, and indicate at least some soil moisture. Sponge spicules represent fresh-water sponges. Diatoms are single-celled algae with a siliceous cell wall. Theygrow in a wide range of aerophilous habitats, including on wet plants and rocks, in damp soils, marshes, wetlands, mudflats, and various standing and flowing aquatic habitats. Often, their silica cells are preserved in sedimentary deposits. Individual taxa have specific growth requirements and preferences with respect to water chemistry. Thus, the presence (and subsequent identification to the species level) of diatoms in paleoenvironmental contexts can provide information about the nature of the local environment, including water chemistry, hydrologic conditions, and substrate characteristics. These data, coupled with input about localgeology, hydrology, soil characteristics, pollen and phytoliths, provide evidence of the paleoenvironmental setting. In these phytolith samples, diatoms are noted, but not identified beyond the split of "pennate" and "centric" forms. Often, centric diatoms indicate wet conditions, while some of the pennate diatoms are cosmopolitan, occurring nearly everywhere. Both diatoms and sponge spicules can be transported with sediment. As an illustration, recovery of sponge spicules in upland soils is noted to accompany loess deposits derived from Illinois floodplains (Jones and Beavers 1963).

DISCUSSION

Broad spectrum diets are hypothesised to have been an important transition strategy that allowed occupation of previously marginal regions and/or environments during the terminal phase of the last glaciation. As such, exploitation of low trophic resources including toxic nuts and grass seeds become an example of this strategy. Pollen, phytolith, and starch analysis of six sediment samples (Table 1) recovered at different depths from EU 1 in the Billabong Leveeseeks to identify plants processed and address coastal/riverine/wetland resources selected.

The majority of the pollen is represented by three taxa: Myrtaceae, Amaranthaceae, andHigh-spine Asteraceae (Figure 1, Table 2), representing plants in the Myrtle family, the goosefoot family, and sunflower family. Several members of the Myrtaceae produce edible fruit, such as guava, Java plum, and others, that may have been collected, processed, and eaten. Woody Myrtaceae have aromatic leaves containing oil glands. *Eucalyptus* is a member of this family and is likely represented in this collection of pollen. Due to similarity in morphology and size of pollen, it is unrealistic to separate Myrtaceae pollen at the genus level unless there are few members of this family known to grow in an area. It is interesting to note that the first for samples submitted exhibit an inverse relationship between Myrtaceae and Amaranthaceae pollen, while Samples designated 4.2 and 5.2, submitted later, were heavily dominated by Amaranthaceae pollen. The larger quantities of Myrtaceae pollen suggest a more closed canopy, while increased Amaranthaceae pollen suggests more sunlight at ground level. Differences in location of these two groups of samples is not well understood to enhance discussion of the significance of the differences in pollen frequencies. Quantities of microscopic charcoal, which may represent burning in a midden layer and also affect visibility ina microscope slide preparation, are greater in Samples 3A, 4.2 and 5.2 than in the other three samples.

Characterizing the local and regional vegetation communities based on the pollen recordrelies on identification of all of the pollen taxa, not simply the most abundant. The arboreal and shrubby portion of the pollen record includes small quantities of *Acacia*, Araliaceae, Arecaceae, *Avicennia*, *Rhizophora*, Myrtaceae, and probable *Lenwebbia* in the Myrtaceae, *Nerium*, Proteaceae, *Salix*, and *Scaevola*. It is likely the *Pinus* pollen represents long distance transport rather than local pine trees. Recovery of both *Avicennia* and *Rhizophora* pollen indicates that the local mangrove population included both genera.

Non-arboreal pollen other than Amaranthaceae and High-spine Asteraceae are observed in small frequencies. Apiaceae, *Artemisia*, Low-spine Asteraceae, Liguliflorae, Brassicaceae, Cyperaceae, Epachradaceae, *Euphorbia*, *Myriophyllum*, two types of Poaceae, Polygonaceae, two species of *Typha* (one that produces single pollen grains and the other that produces tetrads), and cf. *Vitex* represent members of the umbel family, sagebrush or a similar plant, ragweed or marshelder or a similar plant, a member of the chicory tribe of the sunflower family, mustards, sedges, a member of the epachris family, spurge, water milfoil, grasses, a member of the knotweed family, cattails, and vitex or chaste-tree. Wetland indicators include willow, some members of the umbel family, water milfoil, some grasses, and cattails. *Vitex* is a medicinal plant. Ferns are represented by small quantities of three morphotypes of spores withscalloped, reticulate, and smooth surfaces. Young fern sprouts are often collected as food. A few scolecodonts were observed in two of the samples. Spherulites were abundant in Sample 3, rare in Sample 5.2, and absent in the remaining samples. Spherulites are a type of remain that rarely survive acid processing. They are small, globular forms that display radial birefringent patterns. Although some forms of spherulites are observed in dung, they are not diagnostic for the presence of dung.

The first four samples submitted yielded pollen signatures similar to one another. Similarities included moderate to large quantities of Myrtaceae pollen and moderate to large quantities of Amaranthaceae pollen. Several members of the Amaranthaceae (goosefoot family) have edible greens and seeds. These four samples are distinguished from the second set of two samples submitted by containing larger quantities of Myrtaceae pollen. In addition, one of the second set of samples (5.2) contained a moderately large quantity of High-spine Asteraceae pollen. In general, the second set of samples yielded fewer pollen taxa per sample than did individual samples within the first set submitted.

Starches were observed in five of the six samples examined. All of the samples except sample 5.2 yielded lenticular starches, which are typical of large-seeded grasses and also *Marsilea drummondi* (nardoo) and *Crinum flaccidum*, although these plants are reported to be typical of arid landscapes (Judith Field in Torrence and Barton 2006:128). Starches that were spherical to sub-angular with a centric hilum were noted in samples 3A, 4, and 8. Although this starch morphotype is typical of many grass seeds, it is also observed in other seeds and some tubers. It is considered to general to assign to a specific botanic taxon. A single small (20µ), sub-triangular starch was recorded in sample 4.2. At present, this starch remains unidentified. It is not large enough to match with starches from ginger or cheeky yam, nor is the hilum placedclose to one of the angles. Instead, this starch is slightly angular with a nearly centric or slightly eccentric hilum.

Microscopic charcoal was particularly abundant in samples 3A, 4.2, and 5.2. Samples 4,3, and 8 yielded smaller quantities of microscopic charcoal in descending order. Microscopic charcoal likely registers proximity to middens or economic activity involving fire. Alternatively, itmay represent natural fires on the landscape.

The phytolith record is dominated by Festucoid phytoliths including dendriforms, rondels,and trapeziforms (Figure 2), representing cool season grasses. This class of phytoliths is more abundant in the original four for samples submitted than in the additional two samples examined. This appears to be largely a matter of preservation, as increased quantities of bulliforms and elongates were observed in the additional two samples submitted. As described above, bulliforms and elongates are typical of grasses, but cannot be used to identify any particular type of grass. Grass short cells are more prone to dissolution because they are smaller in size than the larger, more general forms such as bulliforms. Saddle-shaped Chloridoid phytoliths represent warm season, short grasses. They are present in all samples, but not particularly abundant. Panicoid phytoliths include bilobates and crosses, present in all samples, and a few polylobates. Bulliforms, trichomes, and all forms of elongates, are generalized forms that do not contribute to an interpretation of the types of grasses growing locally. Cyperaceae phytoliths were noted in two samples, suggesting sedges grew with grasses on the mounds. Phytoliths typical of dicotyledonous (dicot) plants were observed in all samples, although they were not sufficiently diagnostic to contribute to understanding the local vegetation community. A single body described as a sunburst shape recovered in Sample 8 probably represents silicified plant hairs.

Pennate diatoms were noted in widely varying frequencies and five of the six samples examined. Sponge spicules were observed in all six samples and severe esters were noted inone of the samples, providing a significant wetland signature for these mound deposits. A single centric starch, typical of grass seeds, was observed in sample 5.2.

SUMMARY AND CONCLUSIONS

Six sediment samples from a billabong in the Calperum Floodplain were examined for pollen, phytolith, and starch remains. Research questions concerning the role and significanceof earth mounds within regional Aboriginal coastal/riverine/wetland practices during the mid- to late Holocene have been posed. Obtaining baseline pollen and phytolith signatures for this billabong is expected to provide evidence of local vegetation that may address the purported introduction of broad-spectrum diets at this time. At a minimum, it provides a description of local vegetation for the mid-to late-Holocene mounds. Recovery of starches is expected to provide additional local vegetation information and possibly more direct evidence of plant exploitation.

Situation of these Australian Indigenous earth mounds in the Calperum floodplain of northern Cape York and the Murray Darling Basin suggests that the earth mounds were tied toa wetland system. Pollen and phytolith evidence of the plants growing in that wetland system include two species of mangrove, willow, fanflower, possibly marshelder, plants in the chicory family of the sunflower family, sedges, water milfoil, some of the grasses, and cattails.
Cyperaceae phytoliths were noted in two samples, while Cyperaceae pollen were observed in four samples. Collectively, evidence of Cyperaceae was recovered in five of the six samples examined, suggesting local growth of sedges across the mounds and/or in the neighboring wetlands. Cool season grasses were dominant, although both short grasses and tall grasses also grew locally. Recovery of diatoms, sponge spicules, and rare severe esters indicate a wetland habitat for the mounds. These wetland habitats would have provided both plant and animal resources for exploitation by occupants of the mounds. Plants would have contributedleafy greens, tubers, and seeds, as well as medicinal compounds, and wood, bark, and fibersthat were important utilitarian items. *Vitex* is a medicinal plant used for women’s health problems.

Starch recovered in the pollen and/or phytolith records indicates the presence of possible seed processing from large-seeded grasses and seeds from other grasses. None of the starches recovered address the question of whether roots/tubers, represented in the pollenrecord, were processed here.

TABLE 1

Provenience data for samples from the Calperum floodplain, Renmark, South Australia.

PRI Sample No.	Sample no.	Feature	Unit	Level (Stat)	Depth (cmbs)	Provenience/ Description	Analysis
3	HIS_2_21_3	HIS_2_21	SU1	3	11–15	Aboriginal earth mound, billabong levee	Pollen, Phytolith/ Starch
3a	RRWWS3_3a	RRWWS3	SU1	4	11–15	Aboriginal earth mound, billabong levee	Pollen, Phytolith/ Starch
4	HIS_2_23_4	HIS_2_23	SU1	3a	16–20	Aboriginal earth mound, billabong levee	Pollen, Phytolith/ Starch
8	HIS_2_22_8	HIS_2_22	SU1	8	36–40	Aboriginal earth mound, billabong levee	Pollen, Phytolith/ Starch
4-2	HCN21_4-2	HCN21	SU1	4	25–35	Aboriginal earth mound, billabong levee	Pollen, Phytolith/ Starch
5-2	HCN20_5-2	HCN20	SU1	5	30–35	Aboriginal earth mound, billabong levee	Pollen, Phytolith/ Starch

TABLE 2
Pollen types observed in samples from the Calperum floodplain.

Scientific Name	Common Name
ARBOREAL POLLEN:	
Acacia	Acacia
Araliaceae	Ginseng family
Arecaceae	Palm family
Avidennia-type	Mangrove
Rhizophora	Mangrove
Myrtaceae	Myrtle family
cf. *Lenwebbia*	Blackball range, main range
Nerium	Oleander
Pinus	Pine
Proteaceae	Protea family
Salix	Willow
Scaevola	Fanflower
NON-ARBOREAL POLLEN:	
Amaranthaceae:	Amaranth family (now includes Chenopodiaceae,these two families were combined based on genetic testing and the pollen category "Cheno- ams")
Apiaceae	Umbel family
Asteraceae:	Sunflower family
Artemisia	Sagebrush
Low-spine	Includes ragweed, cocklebur, sumpweed
High-spine	Includes aster, rabbitbrush, snakeweed, sunflower, etc.
Liguliflorae	Chicory tribe, includes dandelion and chicory
Brassicaceae	Mustard or cabbage family
Cyperaceae	Sedge family
Epachradaceae	Australian heath family
Euphorbia	Spurge

TABLE 2 (Continued)

Scientific Name	Common Name
Myriophyllum	Water milfoil
Poaceae	Grass family
Polygonaceae	Knotweed/smartweed family
Typha angustifolia-type	Narrowleaf cattail
Typha latifolia-type	Broadleaf cattail
Vitex	Vitex, chaste-tree
Indeterminate	Too badly deteriorated to identify
STARCHES:	
Achnatherum (formerly *Oryzopsis*)-type	Indian rice grass seed starch
Globular with centric hilum	Typical of starches produced by grass seeds
Lenticular starch	Typical of starches produced by grass seeds suchas those from wheat grass (*Agropyron*), ryegrass (*Elymus*), or barley grass (*Hordeum*), *Marsilea drummondii* (nardoo), *Crinum flaccidum*
Sub-triangular starch	20 µ, immature yam,
SPORES:	
Trilete reticulate	Fern
Trilete, scalloped	Fern
Trilete smooth	Fern
OTHER:	
Scolecodont	Worm jaw
Spherulite	Birefringent, crystalline to semi-crystalline spheroid bodies
Microscopic charcoal	Microscopic charcoal fragments
Total pollen concentration	Quantity of pollen per cubic centimeter (cc) ofsediment

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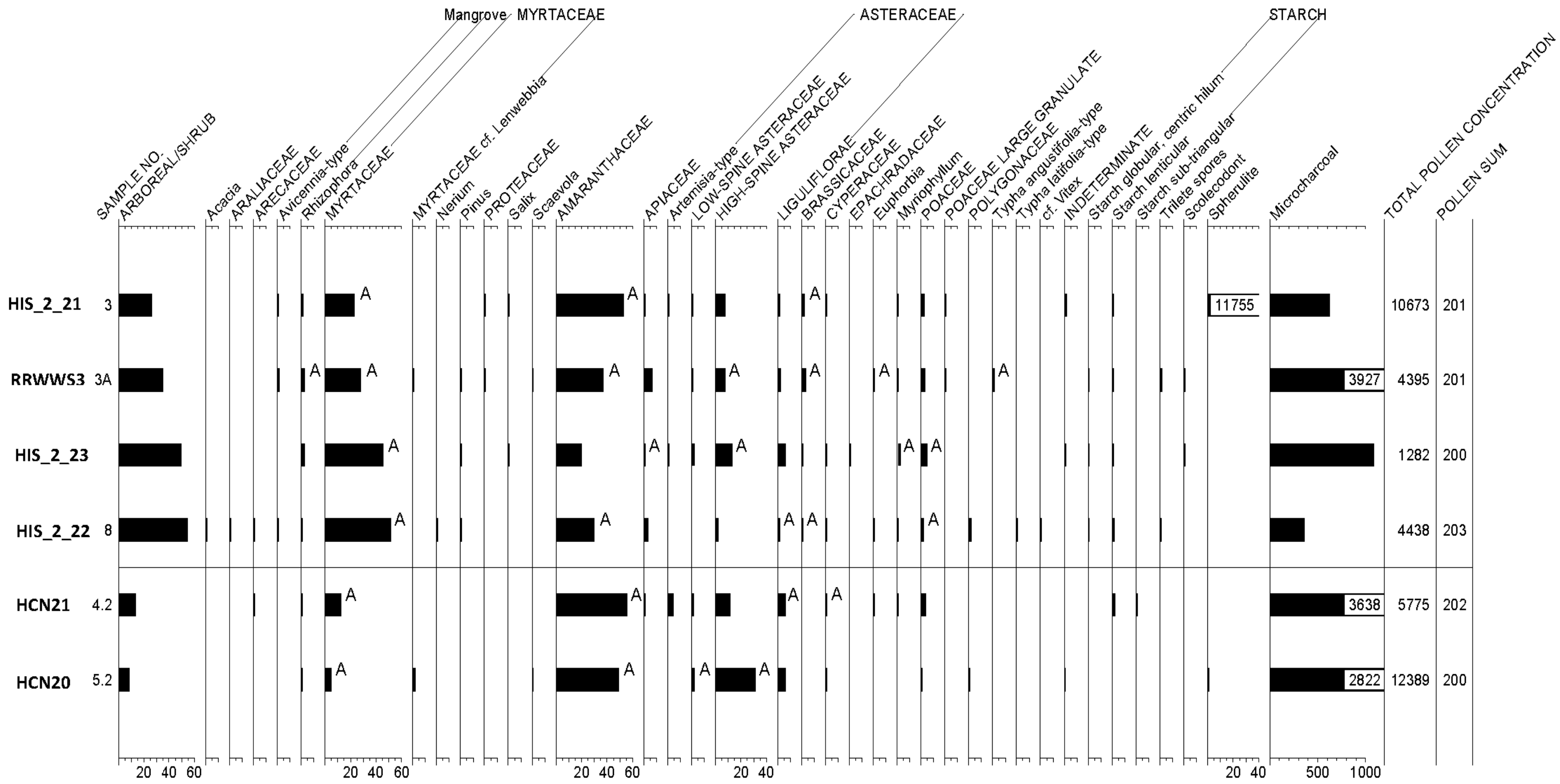


Figure 1: Pollen diagram for samples from Calperum, near Renmark, South Australia, Australia.

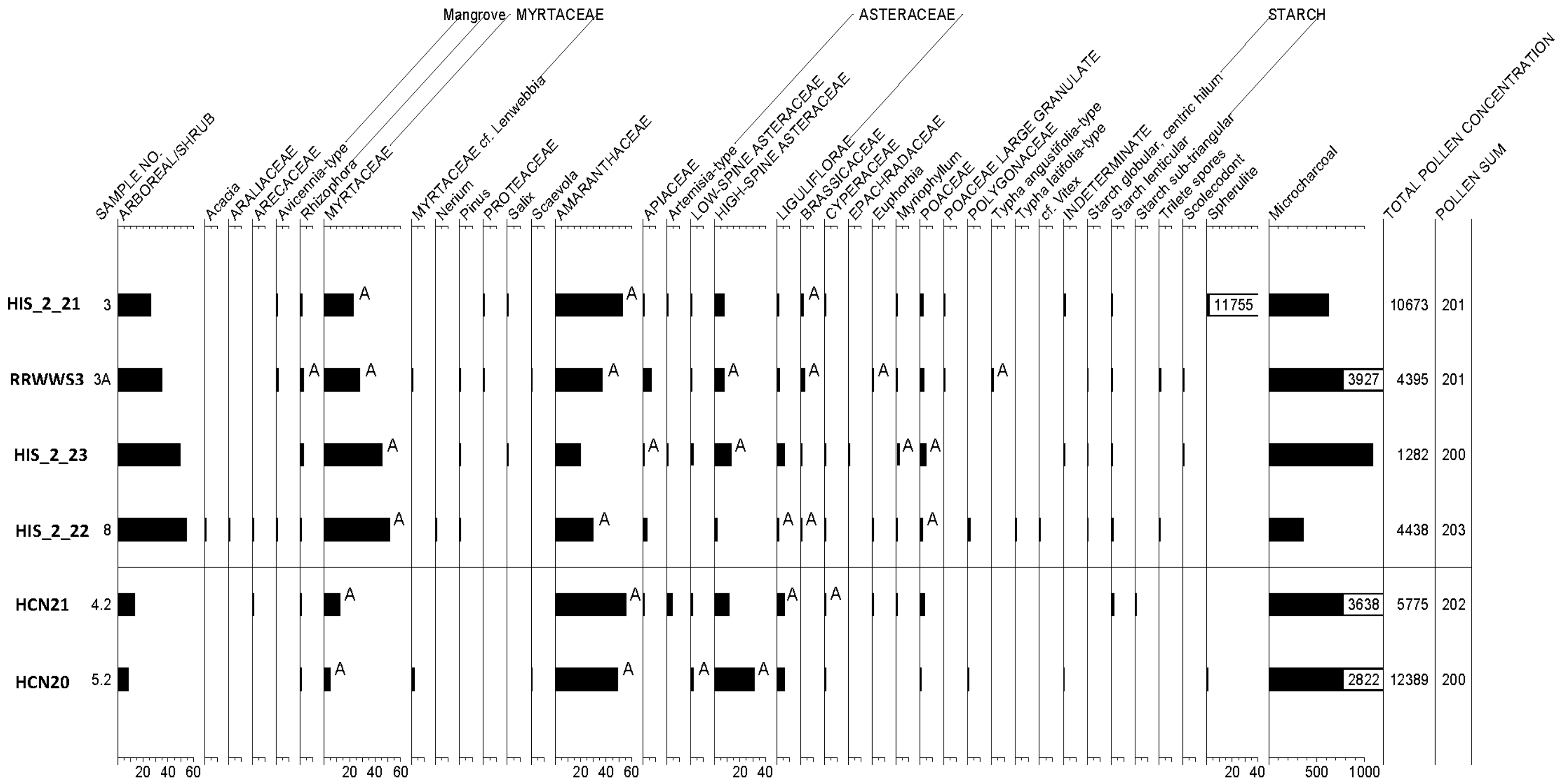


Figure 2: Phytolith diagram for samples from Calperum, near Renmark, South Australia, Australia.

Appendix Three: Mound Survey Data (n = 55)

Table 3A.1: Calperum earth mound survey data.

Date	Feature	Type	Easting	Northing	Land ELM	Land PAT	Pri. Veg	Sec. Veg	Leng. m	Width m	Dist to water m	Ht. cm	Artefacts pcs.	Heat retainer	Comments
Sep. 2018	HIE1	Earth mound	483066	6233224	LEV	FLO	Tree	chen	18	18		50		<10cm	Low levee, clay to 5cm+
Sep. 2018	HIE2	Earth mound	483008	6233211	LEV	FLO	Tree	chen	18	18		30		<10cm	Ashy, not mounded, clay nodules
Sep. 2018	RRWWS3	Earth mound	473974	6229709	LEV	FLO	Tree	chen	45	30		45		<5cm	Surface disrupted H/R visible
Sep. 2018	RRWWN4	Earth mound	474686	6230331	LEV	FLO	Tree	chen	30	30		50		<5cm	Intact surface, little H/R visible but to 5cm
Sep. 2018	RRCW_2_5	Earth mound	473400	6232172	LEV	FLO	Tree	chen	13	10		10	4 chert	<5cm	Lag deposit
Sep. 2018	RRCW_2_6	Earth mound	472963	6231710	LEV	FLO	Tree	chen	12	3		0.1	5 chert		Hearth feature very eroded crossed by road
Sep. 2018	RRCW_2_7	Earth mound	472957	6231712	LEV	FLO	Tree	chen	13	13		0.1			Lag deposit crossed by road
Sep. 2018	RRCW_2_8	Earth mound	472927	6231666	LEV	FLO	Tree	chen	30	30		0.1	1 chert		Lag deposit crossed by road

Sep. 2018	RRCW_2_9	Hearth	472893	6231483	LEV	FLO	Tree	chen	4	3		0.1			Single earth oven/hearth feature
Sep. 2018	RRCW_2_10	Earth mound	472853	6231352	LEV	FLO	Tree	chen	9	9		5			Deflated earth mound
Sep. 2018	RRCW_2_11	Earth mound	472865	6231117	LEV	FLO	Tree	chen	16	16	15	20	1 silcrete	<2 cm	Very humic, no obvious heat retainer on mound
Sep. 2018	RRCE_2_12	Earth mound	473113	6230784	LEV	FLO	Tree	chen	16	16		0.1	1 silcrete, 2 chert	<10cm	Deflated, clay nodules
Sep. 2018	HIS_2_13	Earth mound	479499	6231234	LEV	FLO	Tree	chen	10	5		30	2 silcrete, 1 chert, 1 grindstone	<10cm	Lag deposit , clay nodules
Sep. 2018	HIS_2_14	Earth mound	479509	6231251	LEV	FLO	Tree	chen	13	13		0.1	5 grindstone fragments	<5cm	Very eroded, clay nodules
Sep. 2018	HIS_2_15	Earth mound	479143	6231344	LEV	FLO	Tree	chen	11	11		0.1		< 10 cm	Eroded earth mound, ashy soil
Sep. 2018	HIS_2_16	Earth mound	479151	6231343	LEV	FLO	Tree	chen	11	11		30		<5cm	Eroded earth mound, ashy soil, some shell
Sep. 2018	HIS_2_17	Earth mound	480001	6231056	LEV	FLO	Tree	chen	7	4		0.1		<10 cm	Burnt clay nodules, no ashy soil, no characoal, shell, or lithics
Sep. 2018	HIS_2_18	Earth mound	480011	6231075	LEV	FLO	Tree	chen	13	13		20		<10 cm	Ashy soil, rabbit damage

Sep. 2018	HIS_2_19	Earth mound	480049	6231014	LEV	FLO	Tree	chen	14	14		0.1		<10 cm	Ashy soil, rabbit damage
Sep. 2018	HIS_2_20	Earth mound	479593	6231338	LEV	FLO	Tree	chen	12	12		10	3 silcrete, 2 chert	<3 mm	Ashy soil, shell
Sep. 2018	HIS_2_21	Earth mound	479553	6231323	LEV	FLO	Tree	chen	30	30		50	4 silcrete	<10 cm	Large area, prominent location, ashy, shell
Sep. 2018	HIS_2_22	Earth mound	479575	6231222	LEV	FLO	Tree	chen	50	50		60		<10 cm	Large area, prominent location, ashy, shell
Sep. 2018	HIS_2_23	Earth mound	479670	6231270	LEV	FLO	Tree	chen	30	30		50		<10 cm	Large area, prominent location, ashy, shell
May 2018	RRCW_2_24	Earth mound	472971	6231281	LEV	FLO	Tree	chen	20	20	50	40		<10 cm	Ashy soil, shell, rabbit damage
Apr./Sep. 2016	RIBB2	Earth mound	476550	6231077	LEV	FLO	Tree	form	17	5	6	15		<5cm	Burnt clay nodules, no ashy soil, no charcoal, shell, or lithics
Apr./Sep. 2016	RIBB3	Earth mound	476515	6231131	LEV	FLO	Tree	bare	20	20	2	20		<5cm	Mesembryanthemum present, ashy humic soil, burnt clay nodules, no shell
Apr./Sep. 2016	RIBB4	Earth mound	476837	6231130	LEV	FLO	Tree	form	11	11	2	20		<5cm	Mesembryanthemum present, ashy humic soil, burnt clay nodules, no shell
Apr./Sep. 2016	RIBB5	Earth mound	476887	6231147	LEV	FLO	Tree	form	9	9	3	15		<5cm	Mesembryanthemum present, ashy humic soil, burnt clay nodules, no shell
Apr./Sep. 2016	RIBB6	Earth mound	477016	6231254	LEV	FLO	Tree	form	10	7	3	20		<5cm	Mesembryanthemum present, ashy humic soil, burnt clay nodules, no shell

Apr./Sep. 2016	RIBB7	Natural mound	476954	6231262	LEV	FLO	Tree	chen	23	23	2	20		<5cm	Covered by alluvium, no ashy soil, thin scatter of small burnt clay nodules
Apr./Sep. 2016	RRCW8	Earth mound	477954	6231942	LEV	FLO	Tree	chen	19	17	60	25		<5cm	Mesembryanthemum present, burnt clay nodules but no shell fragments
Apr./Sep. 2016	RRCW9	Earth mound	477996	6232012	LEV	FLO	Tree	chen	24.5	20	36	50		<5cm	Mesembryanthemum present, burnt clay nodules but no shell fragments, rabbit damage
Apr./Sep. 2016	RRCW10	Earth mound	477975	6232297	LEV	FLO	Tree	chen	16	16	60	40		<5cm	Mesembryanthemum present, burnt clay nodules but no shell fragments, rabbit damage
Apr./Sep. 2016	RRCW11	Earth mound	478106	6232325	LEV	FLO	Tree	chen	9	9	80	10		<5cm	Mesembryanthemum present, burnt clay nodules but no shell fragments, rabbit damage
Apr./Sep. 2016	RRCE12	Earth mound	478123	6232022	LEV	FLO	Tree	chen	15	15	2	20		<5cm	Covered in alluvium with ashy, humic soil, small hearth nearby
Apr./Sep. 2016	RRCE13	Pit	478123	6231975	LEV	FLO	Tree	chen	1	1	2	50		NA	Possible Proto earth mound site
Apr./Sep. 2016	RRCE14	Earth mound	478162	6232599	LEV	FLO	Tree	chen	20	20	80	30		<5cm	Badly deflated, rabbit activity, shell, burnt clay nodules on surface, eroding from edge
Apr./Sep. 2016	HCS19	Earth mound	478549	6232598	LEV	FLO	Tree	chen	20	20	30	20	4 silcrete flakes, heat affected	<5cm	Circular, ashy soil, rabbit activity, 1 metre high foliage
Apr./Sep. 2016	HIBB15	Earth mound	479572	6232000	LEV	FLO	Tree	chen	21	20	3	50		<5cm	Ashy, humic soil, rabbit damage, shell, burnt clay
Apr./Sep. 2016	HIBB16	Earth mound	479527	6231952	LEV	FLO	Tree	chen	10	10	2	10		<5cm	Ashy, humic soil, rabbit damage, shell, burnt clay

Apr./Sep. 2016	HIBB17	Earth mound	479640	6231888	LEV	FLO	Tree	chen	10	10	10	10		<5cm	Ashy feature obscured by vegetation and tree debris, small clay nodules, no shell
Apr./Sep. 2016	HIBB18	Earth mound	479653	6231868	LEV	FLO	Tree	chen	15	15	30	10		<5cm	Ashy feature obscured by vegetation and tree debris, HR
Apr./Sep. 2016	HCN20	Earth mound	482548	6235143	LEV	FLO	Tree	chen	20	14	62	20	silcrete/chert flakes, deb.	<10 cm	Ashy soil matrix, shell, small to large burnt clay nodules
Apr./Sep. 2016	HCN21	Earth mound	482171	6234929	LEV	FLO	Tree	chen	40	23	42	50	silcrete/chert flakes, deb.	<5cm	Ashy soil matrix, shell, small to large burnt clay nodules
Apr./Sep. 2016	HCN22	Earth mound	482100	6234893	LEV	FLO	Tree	chen	25	25	40	50	silcrete/chert flakes, deb.	<5cm	Ashy soil matrix, shell, small to large burnt clay nodules
Apr./Sep. 2016	HCN23	Earth mound	482061	6234821	LEV	FLO	Tree	chen	22	22	40	25	silcrete/chert flakes, deb.	<5cm	Ashy soil matrix, shell, small to large burnt clay nodules
Apr./Sep. 2016	HCN24	Earth mound	481999	6234755	LEV	FLO	Tree	chen	16	16	40	40		<5cm	Ashy soil matrix, shell, small to large burnt clay nodules, tree debris
Apr./Sep. 2016	HCN25	Earth mound	481873	6234575	LEV	FLO	Tree	chen	20	20	63	20		<5cm	Ripped feature, prior rabbit damage
Apr./Sep. 2016	HCN26	Earth mound	481797	6234406	LEV	FLO	Tree	chen	3	3	59	0.1		<5cm	Burnt clay nodules, no ashy soil, no characoal, shell, or lithics
Apr./Sep. 2016	HCN27	Earth mound	481762	6234262	LEV	FLO	Tree	chen	30	30	42	20		<5cm	Ashy soil matrix, shell, small burnt clay nodules, tree debris
Apr./Sep. 2016	HCN28	Earth mound	481793	6233997	LEV	FLO	Tree	chen	20	20	30	20		<5cm	Ashy soil matrix, shell, small burnt clay nodules, tree debris

Apr./Sep. 2016	HCN29	Earth mound	481706	6233911	LEV	FLO	Tree	chen	20	15	52	60		<5cm	Raised feature Amazon entrance, small clay nodules, rabbit damage
Apr./Sep. 2016	HCN30	Earth mound	481542	6233699	LEV	FLO	Tree	chen	20	20	62	10		<5cm	Ashy soil, burnt clay nodules, shell, tree debris
Apr./Sep. 2016	HCN31	Earth mound	481210	6233657	LEV	FLO	Tree	chen	25	20	35	50	Scald with artefacts to north	<5cm	Ashy soil, burnt clay nodules, shell, tree debris
Apr./Sep. 2016	MRC1	Earth mound	476985	6230933	LAC	FLO	Tree	chen	16	16	200	50		<5cm	North eastern edge of Lake Meretti lake, burnt clay nodules, tree debris, underlying sand base

Appendix Four: Sediment Data

1. Earth Mound Data

Table 4A.1: Earth Mounds grain size data.

Code	Level	Grams 4mm	Grams 2mm	Grams 1mm	Grams 0.5mm	Grams 0.25mm	Grams 0.125mm	Grams 0.63mm	Grams Base	Post weight	Start weight	Loss in weight gms
HIS_2_21	1			0.389	0.24	10.713	25.424	16.301	5.529	58.596	59.312	0.72
	3			0.42	2.411	9.823	26.682	16.818	7.357	63.511	63.874	0.36
	4			0.439	1.719	7.365	21.983	15.652	7.786	54.944	55.338	0.39
	5			0.534	2.371	8.635	21.017	14.328	8.578	55.463	55.908	0.44
	6			0.51	2.329	10.025	24.525	15.183	7.143	59.715	60.183	0.47
HIS_2_22	1			0.486	4.018	10.388	20.993	14.364	8.763	59.012	59.291	0.28
	2			0.456	3.57	7.963	16.801	11.893	8.730	49.413	49.739	0.33
	4			0.635	5.394	10.018	27.571	12.543	1.726	57.887	58.611	0.72
	5			0.404	2.95	6.891	24.323	5.785	0.583	40.936	41.637	0.70
	6			0.387	3.545	8.276	28.396	5.649	0.475	46.728	47.418	0.69
	7			0.443	3.247	9.58	28.444	6.064	0.492	48.27	49.22	0.95
	8		9.402	17.837	2.632	3.542	5.175	4.999	2.326	45.913	45.861	-0.05
	9			1.451	7.786	12.454	15.059	7.504	3.76	48.014	48.544	0.53
HIS_2_23	1		0.031	0.19	2.446	8.244	34.97	15.898	6.65	68.429	68.634	0.20
	2			0.4	2.813	8.686	31.868	15.812	9.179	68.758	69.104	0.35
	3			0.216	1.943	7.256	32.383	16.138	11.309	69.245	69.66	0.41
	4			0.107	0.743	4.686	25.283	9.739	7.367	47.925	48.499	0.57
	5			0.121	1.097	9.085	35.601	15.737	11.208	72.849	73.356	0.51
	6			0.129	1.583	13.45	34.138	14.573	8.097	71.97	72.211	0.24
	7			0.142	1.325	15.364	29.217	11.28	5.884	63.212	63.547	0.33
RRWWS3	1			0.212	2.506	15.267	23.852	10.596	5.512	57.945	58.093	0.15
	2			0.274	4.35	14.466	17.953	7.58	0.981	45.604	46	0.40
	3			0.281	5.009	16.674	24.276	10.093	1.568	57.901	58.305	0.40
	4			0.162	3.8	14.881	33.469	9.134	0.325	61.771	62.323	0.55
	5			0.11	2.832	12.564	30.908	2.441	0.169	49.024	49.714	0.69
	6			0.209	3.974	11.988	23.903	2.732	0.073	42.879	43.377	0.50
	7			0.279	5.201	23.35	21.634	0.528	0.083	51.075	51.428	0.35
	8			0.486	8.524	34.943	6.877	0.122	0.014	50.966	51.298	0.33
HCN20 <3	1		0.439	3.941	2.932	11.944	33.059	2.248	0.466	55.029	55.455	0.43
	2		0.237	2.432	2.538	30.086	19.640	0.784	0.211	55.928	56.074	0.15
	3		0.155	2.127	1.745	6.198	15.881	13.519	7.818	47.443	48.036	0.59
	4		0.367	2.375	1.947	9.428	24.864	18.122	13.629	70.732	71.416	0.68
	5		0.432	3.202	1.581	9.323	21.646	15.991	11.182	63.357	63.561	0.20
	6		0.356	3.774	2.366	11.165	19.84	13.141	7.873	58.515	58.809	0.29
	7		0.327	2.838	2.107	9.780	25.754	18.997	13.552	73.355	74.115	0.76
HCN21<3r	1		0.306	4.021	3.814	23.038	23.102	0.621	0.157	55.059	55.923	0.86
	2		0.097	2.239	1.935	21.941	32.889	0.493	0.084	59.678	60.106	0.43
	3		0.113	2.000	1.396	8.040	38.991	6.857	0.793	58.19	58.700	0.51
	5	0.222	1.242	2.368	0.871	5.751	29.258	24.54	14.115	78.367	78.691	0.32
	6	0.46	0.783	1.728	0.647	6.372	27.253	23.174	11.543	71.96	72.205	0.24
	7		0.614	1.289	0.814	5.821	26.510	20.398	10.900	66.346	66.800	0.45
	8	0.302	0.517	1.234	0.423	5.681	35.704	21.493	9.297	74.651	75.202	0.55
	9	0.946	1.664	5.193	1.222	5.616	23.297	13.562	5.911	57.411	56.625	-0.79

Table 4A.2: Earth mound magnetic susceptibility data.

Code	Date	Level	Sieve	LF e-9	HF e-9	FD%	LF e-9	HF e-9	FD%
HIS_2_21	23/01/2020	1	<1mm	226.5	207.4	8.40	226.7	203.7	10.1
	23/01/2020	1	<1mm	225.6	204.8	9.20			
	23/01/2020	1	<1mm	226.7	201.9	10.9			
	23/01/2020	1	<1mm	227.9	200.6	12.0			
	23/01/2020	2	<1mm	204.9	187.2	8.70	205.2	186.5	9.2
	23/01/2020	2	<1mm	205.5	185.8	9.60			
	23/01/2020	3	<1mm	193.8	180.6	6.80	196.1	180.9	7.7
	23/01/2020	3	<1mm	197.2	182.8	7.30			
	8/01/2020	3	<1mm	197.6	184.5	6.62			
	8/01/2020	3	<1mm	195.7	175.6	10.3			
	23/01/2020	4	<1mm	179.7	167.2	7.00	179.0	163.9	8.3
	23/01/2020	4	<1mm	181.3	164.5	9.23			
	23/01/2020	4	<1mm	172.1	162.8	5.35			
	23/01/2020	4	<1mm	182.8	161.2	11.8			
	23/01/2020	5	<1mm	178.5	167.2	6.32	178.9	165.8	7.3
	23/01/2020	5	<1mm	179.3	164.3	8.34			
	23/01/2020	6	<1mm	162.1	151.1	6.78	162.7	151.8	6.7
	23/01/2020	6	<1mm	163.3	152.5	6.58			
HIS_2_22	9/01/2020	1	<1mm	1133	1041	8.07	1134.5	1050.6	8.1
	9/01/2020	1	<1mm	1136	1044	8.13			
	9/01/2020	2	<1mm	1196	1093	8.57	1197.0	1094.0	8.6
	9/01/2020	2	<1mm	1198	1095	8.61			
	9/01/2020	3	<1mm	1380	1266	8.29	1383.5	1268.50	8.3
	9/01/2020	3	<1mm	1387	1271	8.36			
	9/01/2020	4	<1mm	1617	1482	8.33	1617.5	1486	8.1
	9/01/2020	4	<1mm	1618	1490	7.90			
	9/01/2020	5	<1mm	1519	1401	7.76	1525.5	1400	8.2
	9/01/2020	5	<1mm	1532	1399	8.65			
	9/01/2020	6	<1mm	1312	1206	8.09	1313.0	1206.5	8.1
	9/01/2020	6	<1mm	1314	1207	8.16			
	9/01/2020	7	<1mm	883.7	804.8	8.93	881.1	805.75	8.6
	9/01/2020	7	<1mm	878.4	806.7	8.17			
	9/01/2020	8	<1mm	673.2	619.4	8.00	678.1	621.5	8.3
	9/01/2020	8	<1mm	682.9	623.6	8.68			
	9/01/2020	9	<1mm	542.0	503.0	7.12	540.9	503.25	6.9
	9/01/2020	9	<1mm	539.7	503.5	6.71			

Table 4A.2: continued.

HIS_2_23	9/01/2020	1	<1mm	576.8	533.2	7.55	584.1	535.625	8.3
	9/01/2020	1	<1mm	588.8	534.3	9.26			
	9/01/2020	1	<1mm	585.8	536	8.5			
	9/01/2020	1	<1mm	584.8	539	7.84			
	9/01/2020	2	<1mm	719	649.3	9.69	720.0	652.733	9.3
	9/01/2020	2	<1mm	717.7	658.5	8.25			
	9/01/2020	2	<1mm	723.3	650.4	10.1			
	9/01/2020	3	<1mm	658	602.5	8.43	654.0	601.8	8.0
	9/01/2020	3	<1mm	650	601.1	7.65			
	9/01/2020	4	<1mm	323.5	292	10.00	326.5	293.05	9.5
	9/01/2020	4	<1mm	329.5	294.1	9.09			
	9/01/2020	5	<1mm	274.8	259.6	5.53	273.4	258.05	5.6
	9/01/2020	5	<1mm	272	256.5	5.71			
	9/01/2020	6	<1mm	263.7	244.9	7.12	262.4	243.85	7.1
	9/01/2020	6	<1mm	261.1	242.8	7.00			
	9/01/2020	7	<1mm	245.5	229.1	6.68	246.8	229.3	7.1
	9/01/2020	7	<1mm	248	229.5	7.47			
RRWW3S	9/01/2020	1	<1mm	574.3	535.2	6.81	575.4	535.2	7.0
	9/01/2020	1	<1mm	576.4	535.2	7.14			
	9/01/2020	1b	<1mm	439.6	396.7	9.76	439.4	402.33	8.4
	9/01/2020	1b	<1mm	438.1	404.5	7.68			
	9/01/2020	1b	<1mm	440.5	405.8	7.89			
	9/01/2020	1c	<1mm	316	286.8	9.24	315.8	289.50	8.3
	9/01/2020	1c	<1mm	313.6	289.3	7.75			
	9/01/2020	1c	<1mm	317.9	292.4	8.04			
	9/01/2020	2	<1mm	526.8	490.5	6.91	526.7	489.45	7.1
	9/01/2020	2	<1mm	526.5	488.4	7.24			
	9/01/2020	2b	<1mm	391.9	360.0	8.13	392.4	360.75	8.1
	9/01/2020	2b	<1mm	392.9	361.5	8			
	9/01/2020	2c	<1mm	298	280.7	5.79	290.5	281.85	5.5
	9/01/2020	2c	<1mm	283	283.0	5.12			
	9/01/2020	3a	<1mm	494.7	462.3	6.55	496.2	462.3	6.8
	9/01/2020	3a	<1mm	497.7	462.3	7.1			
	9/01/2020	3c	<1mm	264.6	240.3	9.17	257.70	237.93	7.5
	9/01/2020	3c	<1mm	252.3	237.5	5.85			
	9/01/2020	3c	<1mm	256.2	236.0	7.49			

Table 4A.2: continued.

HCN20	10/07/2020	1	<3mm	988.5	897.7	9.2	991.2	901.9	9.0
	10/07/2020	1	<3mm	990	906.3	8.45			
	10/07/2020	1	<3mm	995	901.8	9.38			
	10/07/2020	2	<3mm	684.1	625	8.64	683.2	616.0	9.8
	10/07/2020	2	<3mm	683.9	613	10.4			
	10/07/2020	2	<3mm	681.6	610	10.4			
	10/07/2020	3	<3mm	660.3	587.3	11.1	661.0	587.7	11.1
	10/07/2020	3	<3mm	661.2	576.4	12.8			
	10/07/2020	3	<3mm	661.3	593.3	10.2			
	10/07/2020	3	<3mm	661.1	593.9	10.2			
	10/07/2020	4	<3mm	522.1	476.4	8.75	527.0	485.9	7.8
	10/07/2020	4	<3mm	530.5	492.5	7.17			
	10/07/2020	4	<3mm	528.3	488.9	7.46			
	10/07/2020	5	<3mm	417.9	373.2	10.7	418.5	378.8	9.5
	10/07/2020	5	<3mm	419	381.3	9			
	10/07/2020	5	<3mm	418.7	381.8	8.81			
	10/07/2020	6	<3mm	316.8	277	12.7	316.7	282.9	10.7
	10/07/2020	6	<3mm	316.6	283.8	10.4			
	10/07/2020	6	<3mm	316.6	287.8	9.16			
	10/07/2020	7	<3mm	262.4	230.9	12	257	227.05	11.6
	10/07/2020	7	<3mm	251.6	223.2	11.3			
HCN21	10/07/2020	1	<3mm	1070	1070	7.01	1066.7	1070	7.9
	10/07/2020	1	<3mm	1060	1070	7.85			
	10/07/2020	1	<3mm	1070	1070	8.71			
	10/07/2020	2	<3mm	364.4	333.3	8.53	363.8	332.5	8.6
	10/07/2020	2	<3mm	363.1	332	8.55			
	10/07/2020	2	<3mm	363.9	332.2	8.72			
	10/07/2020	3	<3mm	249.8	230.1	7.87	248.0	229.7	7.4
	10/07/2020	3	<3mm	246.1	229.3	6.85			
	10/07/2020	4	<3mm	168.2	153.6	8.67	169.3	156.7	7.5
	10/07/2020	4	<3mm	170.9	159.6	6.65			
	10/07/2020	4	<3mm	168.9	157	7.04			
	10/07/2020	5	<3mm	264.9	250.8	5.3	265.4	248.3	6.4
	10/07/2020	5	<3mm	266.8	247.5	7.2			
	10/07/2020	5	<3mm	264.6	246.6	6.8			
	10/07/2020	6	<3mm	106.2	102.5	3.42	106.2	103.4	2.6
	10/07/2020	6	<3mm	106.1	104.3	1.7			
	10/07/2020	7	<3mm	99.9	93.6	4.65	99.7	93.3	5.6
	10/07/2020	7	<3mm	99.4	93	6.47			
	10/07/2020	8	<3mm	78	104.1	-33.4	78.7	103.85	-32.0
	10/07/2020	8	<3mm	79.3	103.6	-30.6			
	10/07/2020	9	<3mm	103.9	112.5	-8.46	104.0	109.5	-5.4
	10/07/2020	9	<3mm	104.1	106.5	-2.27			

Table 4A.3: Earth mound LOI data.

sample no.	Code	Level	cruc wt gm	crucible +sample gm	After 100°C gm	After 550°C gm	After 1000°C gm	LOI organic gm	% organic	LOI Carbonate gm	% Carbonate
1	HIS_2_21	1	25.208	34.761	34.501	33.901	33.689	0.6	1.74	0.212	0.61
		2	23.691	32.922	32.658	32.09	31.871	0.568	1.74	0.219	0.67
2		3	24.008	34.265	33.990	33.351	33.073	0.639	1.88	0.278	0.82
		4	23.882	33.52	33.118	32.594	32.306	0.524	1.58	0.288	0.87
3		5	26.732	35.939	35.561	35.001	34.728	0.56	1.57	0.273	0.77
4		6	24.634	34.641	34.288	33.756	33.460	0.532	1.55	0.296	0.86
15	HIS_2_22	1	25.177	33.965	33.603	32.777	32.632	0.826	2.46	0.145	0.43
5		2	24.645	33.055	32.643	31.728	31.511	0.915	2.80	0.217	0.66
6		4	25.534	34.063	33.528	32.751	32.501	0.777	2.32	0.25	0.75
16		5	25.242	32.536	32.000	31.382	31.183	0.618	1.93	0.199	0.62
17		6	26.701	34.184	33.636	33.038	32.885	0.598	1.78	0.153	0.45
7		7	23.083	29.758	29.202	28.653	28.568	0.549	1.88	0.085	0.29
8		8	25.269	23.89	33.314	32.717	32.638	0.597	1.79	0.079	0.24
18		9	26.446	34.852	34.266	33.729	33.641	0.537	1.57	0.088	0.26
11	HIS_2_23	1	24.802	34.097	33.906	33.379	33.137	0.527	1.55	0.242	0.71
9		2	24.900	34.300	34.051	33.500	33.158	0.551	1.62	0.342	1.00
12		3	22.842	32.997	32.692	32.193	31.757	0.499	1.53	0.436	1.33
10		4	24.240	34.770	34.509	34.057	33.698	0.452	1.31	0.359	1.04
13		5	23.968	34.931	34.59	34.122	33.86	0.468	1.35	0.262	0.76
11		6	24.870	33.449	33.120	32.753	32.633	0.367	1.11	0.12	0.36
12		7	24.554	35.287	34.920	34.549	34.418	0.371	1.06	0.131	0.38
21	RRWWS3	1	24.959	34.484	34.221	33.585	33.492	0.636	1.86	0.093	0.27
13		1b	26.186	33.226	32.880	32.498	32.452	0.382	1.16	0.046	0.14
22		1c	24.489	31.837	31.201	30.573	30.513	0.628	2.01	0.06	0.19
14		2	24.243	32.636	32.228	31.668	31.594	0.56	1.74	0.074	0.23
		2b	23.542	32.332	31.742	31.112	31.046	0.63	1.98	0.066	0.21
		2c	23.999	30.814	30.138	29.492	29.434	0.646	2.14	0.058	0.19
15		3a	24.875	36.866	32.496	31.993	31.924	0.503	1.55	0.069	0.21
16		3c	23.739	31.414	30.649	29.978	29.925	0.671	2.19	0.053	0.17
17	HCN20	1	24.301	32.608	32.124	31.510	31.237	0.614	1.91	0.273	0.85
8		2	25.730	33.044	32.449	32.044	31.74	0.405	1.25	0.304	0.94
18		3	24.975	34.507	34.072	33.629	33.230	0.443	1.30	0.399	1.17
9		4	24.637	34.900	34.587	34.275	33.912	0.312	0.90	0.363	1.05
19		5	26.973	37.011	36.728	36.371	35.977	0.357	0.97	0.394	1.07
20		6	23.856	33.793	33.278	32.924	32.556	0.354	1.06	0.368	1.11
10		7	24.130	33.787	32.877	32.499	32.27	0.378	1.15	0.229	0.70
1	HCN21	1	23.289	31.903	31.408	30.895	30.535	0.513	1.63	0.36	1.15
2		2	25.916	34.511	33.912	33.599	33.395	0.313	0.92	0.204	0.60
4		4	24.751	33.875	33.569	33.312	33.184	0.257	0.77	0.128	0.38
5		5	25.772	36.637	36.392	36.121	35.996	0.271	0.74	0.125	0.34
6		6	23.915	35.120	34.903	34.649	34.531	0.254	0.73	0.118	0.34
7		7	23.960	33.899	33.606	33.372	33.276	0.234	0.70	0.096	0.29
8		8	22.563	33.814	33.548	33.361	33.268	0.187	0.56	0.093	0.28
9		9	25.19	35.176	34.763	34.524	34.423	0.239	0.69	0.101	0.29

2. Hunchee Auger Data

Table 4A.4: Grain size.

Code	Level cm	Grams 4 mm	Grams 2 mm	Grams 1 mm	Grams 0.5 mm	Grams 0.25 mm	Grams 0.125 mm	Grams 0.63 mm	Grams Base	Post weight	Start weight	Loss in weight gms
HA	16	9.163	9.513	12.307	9.867	8.847	6.2	4.002	4.094	63.993	64.601	0.61
	19	9.855	10.583	12.967	10.33	8.96	6.5552	4.276	3.359	66.8882	67.468	0.58
	27	9.029	11.207	14.117	11.62	9.199	5.764	3.043	1.3	65.281	65.76	0.48
	42	21.241	16.036	15.27	10.46	7.757	4.617	2.172	0.228	77.78	78.538	0.76
	57	31.808	16.211	13.185	5.97	3.628	1.513	0.374	0.061	72.75	73.548	0.80
	77	41.701	17.132	12.81	3.908	1.885	0.402	0.07	0.025	77.933	78.885	0.95

Table 4A.5: Magnetic Susceptibility.

Code	Level cm	Date	LF e-9	HF e-9
HA	16	12/08/2021	140	138.9
	16	12/08/2021	143	143
	19	12/08/2021	133	133.5
	19	12/08/2021	136.83	126
	27	12/08/2021	126.3	123.3
	27	12/08/2021	124.8	121.1
	42	12/08/2021	125.9	115.8
	42	12/08/2021	121.1	116.1
	57	12/08/2021	114.7	106.5
	57	12/08/2021	111.6	108.5
	77	12/08/2021	92.6	95.4
	77	12/08/2021	93	97.5

Table 4A.6: LOI.

Code		Range cal BP	cruc wt gm	crucible +sample gm	After 100°C gm	After 550°C gm	After 1000°C gm	LOI organic gm	% organic	LOI Carbonate gm	% Carbonate
HA_16	16	4,960–4,846	17.322	27.509	26.818	26.491	26.372	0.33	1.22	0.12	0.44
HA_19	19		15.703	25.06	24.291	24.001	23.882	0.29	1.19	0.12	0.49
HA_27	27	2,292–2,004	15.84	26.167	25.152	24.841	24.704	0.31	1.24	0.14	0.54
HA_42	42		18.233	27.922	26.818	26.537	26.405	0.28	1.05	0.13	0.49
HA_57	57		16.966	27.986	26.455	26.144	25.991	0.31	1.18	0.15	0.58
HA_77	77	12,620–12,195	14.879	24.333	22.689	22.438	22.299	0.25	1.11	0.14	0.61

Appendix Five: Fauna

1. Aquatic gastropod data

Table 5A.1: Aquatic gastropod data for excavated mounds at Calperum.

Mound	Level	Spec. no.	Specimen Condition	Wt.gm	Leng. mm	width mm	Family	Genus	Species	Habitat	Comment
HIS_2_21	1	1	Whole	0.014	4.8	3.4	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire
		2	Whole	0.056	10.7	6.7	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large oval aperture, short impressed spire
		3	Frag.	0.023	9.7	4	Indet.			Indet.	External portion , helicoid
		4	Frag.	0.021	6.6	2.9	Indet.			Indet.	Internal portion , helicoid
		5	Frag.	0.017	7.1	4.3	Indet.			Indet.	External portion , helicoid
		6	Frag.	0.088	3.7	3.4	Indet.			Indet.	External portion , helicoid
		7	Frag.	0.005	3	3.2	Indet.			Indet.	External portion , helicoid
HIS_2_21	2	8	Frag.	0.03	9.9	6.4	Indet.			Indet.	External portion , helicoid
		9	Frag.	0.025	5.8	6.6	Indet.			Indet.	Internal portion , helicoid
		10	Frag.	0.016	6.9	5.5	Indet.			Indet.	External portion , helicoid.
	3	11	Frag.	0.051	6	6.6	Indet.			Indet.	External portion , helicoid, spire intact
		12	Frag.	0.006	8.4	3.3	Indet.			Indet.	External portion , helicoid.
		13	Frag.	0.0005	2.4	1.9	Indet.			Indet.	External portion , helicoid.
HIS_2_21	5	14	Whole	0.011	4.3	3.1	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire.
		15	Whole	0.004	4.7	3	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		16	Whole	1.06	14.9	12.1	Camaenidae	*Cupedora*	*cassandra*	Terrest.	Shell medium, planispiral, 5 whorls, subglobose, slight spire, body whorl rounded, aperture ovate-lunate.
HIS_2_22	2	17	Frag.	0.0005	3.1	2.4	Indet.			Indet.	External portion , helicoid.
		18	Frag.	0.0005	3.3	2.5	Indet.			Indet.	External portion , helicoid.
		19	Frag.	0.0005	2.9	2	Indet.			Indet.	External portion , helicoid.
HIS_2_22	4	20	Single valve	4.64	55.7	39.1	Hyriidae	*Velesunio*	*ambiguus*	Fresh water	Shape variable, thin, anter. rounded, posterior pointed.

Table 5A.1: Continued:

HIS_2_22	5	21	Partial	0.011	5.5	3.8	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire.
		22	Whole	0.366	19.1	11.3	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
HIS_2_22	6	23	Whole	0.0005	3	1.9	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		24	Whole	0.0005	4	2	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		25	Frag.	0.011	6.1	4.5	Indet.			Indet.	External fagment
		26	Frag.	0.012	6.5	2.5	Indet.			Indet.	External fagment
	9	27	Whole	0.077	7.1	5.1	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
HIS_2_23	1	28	Whole	0.344	13.5	8.1	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		29	Whole	0.065	6.7	6.6	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		30	Whole	0.008	5.3	3.3	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire.
		31	Whole	0.15	6	3.2	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire.
		32	Whole	0.11	7.3	3.9	Geomitridae	*Cernuella*	*virgata*	Terrestrial	Small, raised planispiral, 4 whorls, sunken spire, periph. coiled, elong. angul. apert., periph. Keel.
		33	Frag.	0.034	6.8	6.4	Indet.			Indet.	External portion , helicoid.
		34	Frag.	0.13	8.2	3.4	Indet.			Indet.	External portion , helicoid.
		35	Whole	0.004	3.8	0.8	Planorbidae	*Gyraulus*	*meridionalis*	Fresh water	Small, planispiral, 4 whorls, sunken spire, periph. coiled, elong. angul. apert., periph. Keel.
		36	Frag.	0.004	3.3	2.4	Indet.			Indet.	External portion , helicoid.
		37	Frag.	0.008	5.2	3.8	Indet.			Indet.	External portion , helicoid.
		38	Frag.	0.021	5.2	4.3	Indet.			Indet.	External portion , helicoid.
		39	Frag.	0.042	7.9	3.7	Indet.			Indet.	External portion , helicoid.
		40	Frag.	0.012	6.6	3.1	Indet.			Indet.	External portion , helicoid.
		41	Frag.	0.014	5.3	3.1	Indet.			Indet.	External portion , helicoid.
		42	Whole	0.0005	3.8	0.7	Planorbidae	*Gyraulus*	*meridionalis*	Fresh water	Small, planispiral, 4 whorls, sunken spire, periph. coiled, elong. angul. apert., periph. Keel.
		43	Frag.	0.006	4.5	2.7	Indet.			Indet.	External portion , helicoid.
HIS_2_23	3	44	Whole	0.006	4	2.5	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire.
		45	Whole	0.011	5.2	1.4	Planorbidae	*Gyraulus*	*meridionalis*	Fresh water	Small, planispiral, 4 whorls, sunken spire, periph. coiled, elong. angul. apert., periph. Keel.

Table 5A.1: Continued:

		46	Whole	0.013	7.7	5	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		47	Partial	0.281	14.8	10.2	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		48	Whole	0.014	7.3	4.5	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		49	Whole	0.034	10.1	4.1	Thiaridae	*Plotiopsis*	*balonnensis*	Fresh water	Fusiform shell, carinated whorls, thin, ovate-lunate aperture, whorls with long. Ridges.
		50	Frag.	0.013	6.5	4.2	Indet.			Indet.	External portion , helicoid.
HIS_2_23	4	51	Whole	0.542	14.4	8.4	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		52	Whole	0.2	15.3	10	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
HIS_2_23	5	53	Frag.	0.015	6.2	3	Indet.			Indet.	External portion , helicoid.
		54	Single valve	0.169	14.1	10.4	Hyriidae	*Velesunio*	*ambiguus*	Fresh water	Shape variable, thin, anter. rounded, posterior pointed.
		55	Whole	0.03	8.1	4.7	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		56	Frag.	0.032	7.4	6.5	Indet.			Indet.	External portion , helicoid.
		57	Frag.	0.028	7.3	4.2	Indet.			Indet.	External portion , helicoid.
HIS_2_23	6	58	Whole	0.013	4.5	3.4	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire.
		59	Whole	0.063	9.8	3.9	Thiaridae	*Plotiopsis*	*balonnensis*	Fresh water	Fusiform shell, carinated whorls, thin, ovate-lunate aperture, whorls with long. Ridges.
		60	Whole	0.03	6.6	4.1	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		61	Frag.	0.026	7.1	6.5	Indet.			Indet.	External portion , helicoid.
RRWWS3	1	62	Whole	0.008	3.6	3.3	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire.
RRWWS3	2	63	Whole	0.011	4.6	4.1	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire.
HCN20	1	64	Frag.	0.05	10	5.4	Indet.			Indet.	External portion , helicoid.
		65	Whole	0.069	9.1	5.8	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		66	Frag.	0.06	6.3	4.7	Indet.			Indet.	External portion , helicoid.
HCN20	2	67	Whole	0.018	8.1	4.5	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		68	Frag.	0.08	10.5	7	Indet.			Indet.	External fragment
		69	Frag.	0.078	11.6	6.2	Indet.			Indet.	External fragment
		70	Frag.	0.067	9	7.9	Indet.			Indet.	External fragment

Table 5A.1: Continued:

		71	Frag.	0.043	6.2	5.3	Indet.			Indet.	External fragment
		72	Frag.	0.038	5.7	5.1	Indet.			Indet.	External fragment
		73	Frag.	0.035	5.3	3.1	Indet.			Indet.	External fragment
HCN21	1	74	Whole	0.038	6.5	2.8	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		75	Single valve	0.071	6.8	5.3	Hyriidae	*Velesunio*	*ambiguus*	Fresh water	Shape variable, thin, anter. rounded, posterior pointed.
		76	Single valve	0.069	6.2	5.1	Hyriidae	*Velesunio*	*ambiguus*	Fresh water	Shape variable, thin, anter. rounded, posterior pointed.
	3	77	Whole	0.016	6.6	5.2	Planorbidae	*Isidorella*	*newcombi*	Fresh water	Small, helicoid, globose, 4 whorls, broad body whorl, large ovate aperture, short impressed spire.
		78	Single valve	0.015	11.1	9	Hyriidae	*Velesunio*	*ambiguus*	Fresh water	Shape variable, thin, anter. rounded, posterior pointed.
		79	Single valve	0.09	9.7	8	Hyriidae	*Velesunio*	*ambiguus*	Fresh water	Shape variable, thin, anter. rounded, posterior pointed.
		80	Whole	0.468	11	6.6	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		81	Frag.	0.056	9.1	6.4	Indet.			Indet.	External fragment
	5	82	Whole	0.0147	10.7	6.1	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		83	Partial	0.07	9.7	5	Planorbidae	*Isidorella*	*hainesii*	Fresh water	Small, helicoid, globose, 5 whorls, broad body whorl, ovate aperture, pointed spire.
		84	Frag.	0.097	6.8	4.3	Indet.			Indet.	External fragment

2. Bone Data

Table 5A.2: Details of bone fragments found in excavated mounds at Calperum.

Site	Level	Size mm	Description	Description	NISP	MNI	Field #	Notes	Common Name
HIS_2_23	7	>3.2	small vertebra	Fish gen. et. sp. indet.	1	1	1		
HIS_2_23	7	>3.2	parietal	Mammalia gen. et. sp. indet.	1	1	2		
HIS_2_24	2	>1	small vertebra	Fish gen. et. sp. indet.	1	1	3		
HIS_2_24	2	>1	left dentary, missing posterior portion, m1-3	Pseudomys bolami	1	1	4		Bollam's Mouse
HIS_2_23		>3.2	Small vertebra	Fish gen. et. sp. indet.	1	1	5		
HIS_2_23	3	>3.2	vertebra and spine	Fish gen. et. sp. indet.	2	1	6		
HIS_2_23	3	>3.2	pelvis fragment	Mammalia gen. et. sp. indet.	1	1	7	Small mammal	
HIS_2_21	2	>3	left talus	Oryctolagus cuniculus	1	1	8		
HIS_2_23	5	1>1	distal phalanx	c.f. Oryctolagus cuniculus	1	1	9		
HIS_2_23	6	>3.2	vertebra (fragment)	Fish gen. et. sp. indet.	1	1	10		
HIS_2_21	3	>3.2	metatarsal	*Oryctolagus cuniculus*	1	1	11		
HIS_2_21	L1.3		I1	*Oryctolagus cuniculus*	1	1	12		

Table 6A.2: Continued:

RRWWS3	1	>3.2	vertebra	*Elapidae* gen. et. sp. indet.	1	1	13		
HIS_2_23	1		left dentary, right talus	*Oryctolagus cuniculus*	2	1	14		
HIS_2_23	7	>3.2	vertebra	Fish gen. et. sp. indet.	1	1	15		
HIS_2_23	4	>3.2	vertebra	*Morelia* sp. indet.	1	1	16		
HIS_2_21	2	>3.2	left femoral head, metacarpal	*Oryctolagus cuniculus*	2	1	17		
HCN21	1	>3	vertebra	Fish gen. et. sp. indet.	1	1	18		
HIS_2_22	1		vertebra	c.f. *Macropodidae* gen. et. sp. indet.	1	1	19		

Appendix Six: Photographs of all Artefacts Found in the Excavated Calperum Earth Mounds

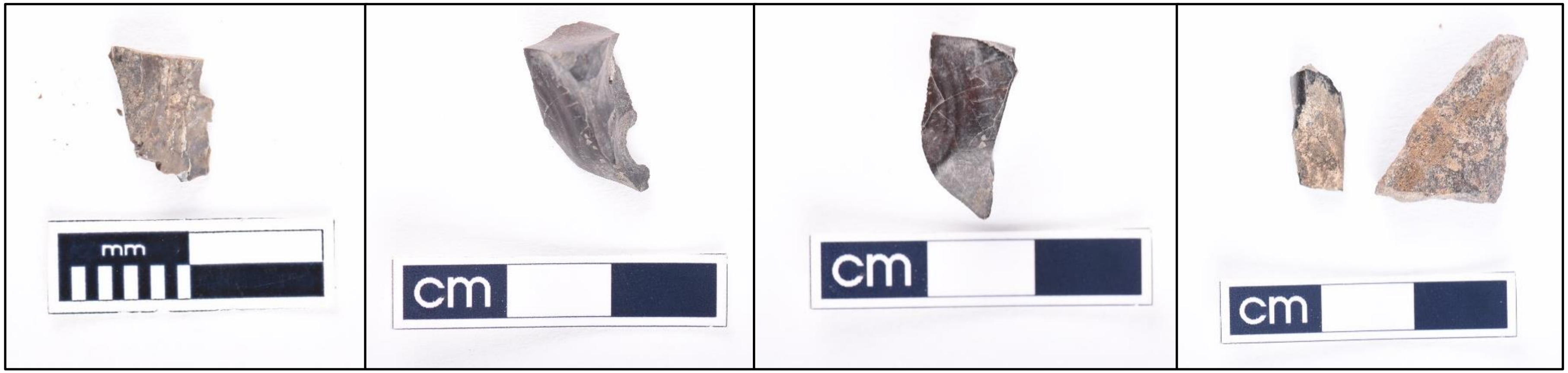


Figure 6A.1: Left to right HIS_2_22 L1 chert flake; HIS_2_22 L5 A, B chert flake (B dorsal view); HIS_2_23 L1 quartzite/silcrete piece.

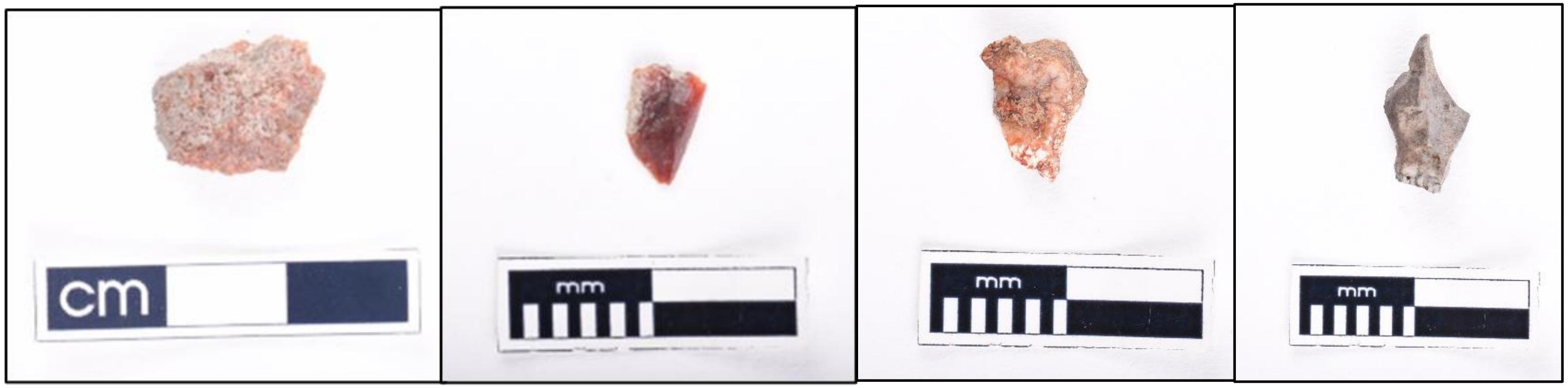


Figure 6A.2: Left to right HIS_2_23 L3 quartzite/silcrete flake; HIS_2_23 L3 chert flake; RRWWS3 L1 chert flake; RRWWS3 L3 chert flake.

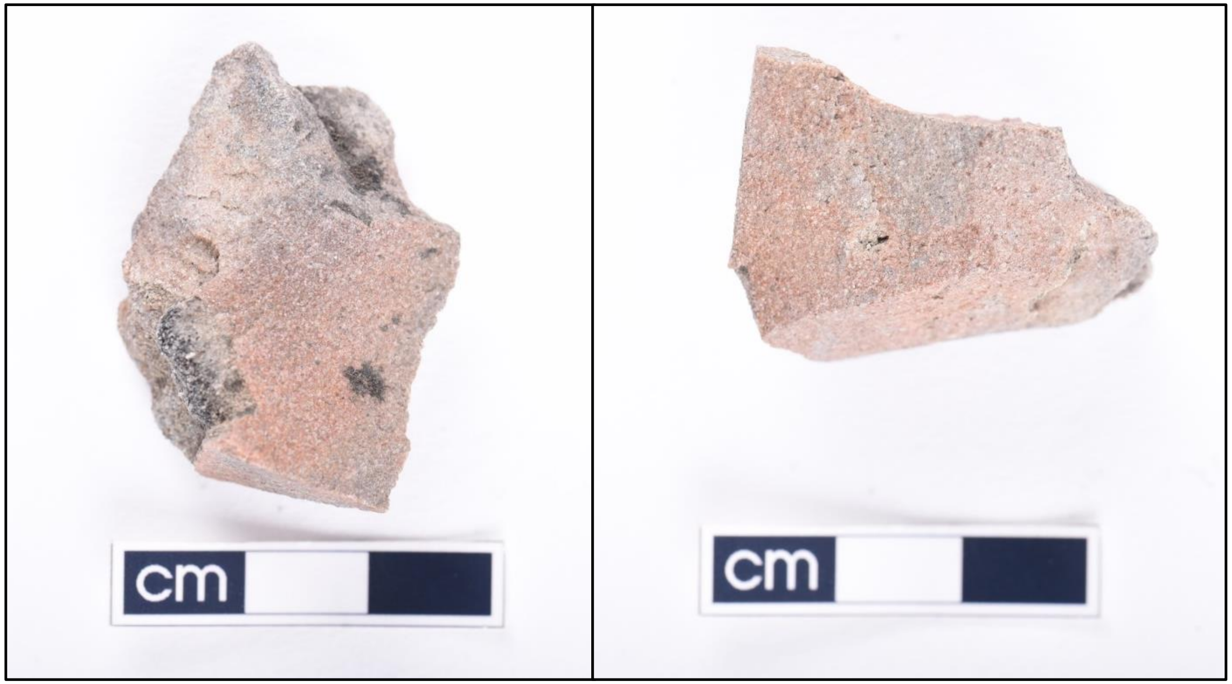


Figure 6A.3: RRWWS3 L6, two views of a silcrete piece.

Figure 6A.4: HCN21 L1, quartzite/silcrete piece.

Figure 6A.5: HCN21 L 2, piece of hard grey clay.

Appendix Seven: Excavation Plan and Excavation Forms

1. Calperum earth mound excavation plan and protocols for September and October 2019, and September 2020.

Project co-ordinator: Bob Jones
Volunteers: Frank Boulden, Cassie Schill, Catherine Morton, Jarrad Kowlessar, Georgina Tuckwell
Supervisors: Professor Amy Roberts, Assoc. Prof. Ian Moffat.

Floodplain locations:

1. September 2019 Location: South Hunchee Island at the Double Thookle Billabong complex for mounds HIS_2_21 and HIS_2_22.
2. October 2019—Locations: South Hunchee Island at the Double Thookle Billabong for mound HIS_2_23 and at Ral Ral Wide Water on Reny Island for mound RRWWS3.
3. September 2020 Location: Calperum upper floodplain at Hunchee Creek north for mounds HCN20 and HCN 21.
4. April 2021 location: Calperum upper floodplain for auger sampling of non-mound sediments.

Projected activities:

1. Drone survey of Thookle Billabong, Ral Ral Wide Water and Hunchee Creek araes.
2. GPR and magnetic (volume) survey of 3 mounds.
3. Excavation of a 0.5 metre square test pit in the 6 mounds designated above.
4. An artefact survey of the immediate surrounding areas of mounds HIS_2_21, HIS_2_22 and HIS_2_23.
5. Magnetic survey of landscape surrounding the mound HIS_2_21, HIS_2_22 and HIS_2_23 locations.

Excavation procedure

1. RMMAC reps to verify and sanction all test pit locations.
2. Site briefing of all participants.
    a. Establishment and layout of work area.
    b. Excavation process.
    c. Site protection measures.
    d. Documentation.
    e. Safety brief
        i. Tools.
        ii. Snakes/insects.
        iii. Heat/sun.
        iv. Water intake.
        v. Rest.
        vi. Trip hazards.
        vii. Strain injuries.
3. Establishment
    a. Pit location—staking, sandbagging and edge-marking pathways, work spaces, installation of protection mesh to Minimise foot traffic within site area.
    b. Sieving location away from the vicinity of the mound.
    c. Recording station.
    d. Establish datum (RTK).

e. Total Station location – resection with RTK GPS readings, site and resection markers established with permanent locators.

4. Excavation
   a. Spits carefully excavated as per stratigraphy or 5 cm increments in absence of stratigraphic layers, ensuring vertical edges maintained as much as possible.
   b. General recording using excavation forms.
   c. TS recording of site detail, major features, pit detail, artefacts, faunal material, mound dimensions, profile etc.
   d. Material removed and transported to the sieving site and passed through a 2 part sieve pack incorporating either 1 or 3 mm and 7 mm sieves.
   e. Sieve fractions bagged, labelled and placed in plastic tubs for later lab analysis at the Flinders archaeology laboratory. Refer associated data management plan below. Material passed through the sieves to be collected on a tarp for return to the excavation pit at conclusion of the excavation.
   f. A representative sample from each sieved fraction will be bagged for flotation and additional finer sieving at the lab.
   g. Pits are to be covered at night and the area delineated with barrier taping.
   h. At the completion of excavating each test pit, representative column samples are to be taken in 5 cm spits from a suitable edge of the excavation encompassing the full depth of the excavation. In addition, a column sediment sample will be taken from a suitable vertical surface for further analysis.

Stop work protocol

1. If human skeletal material is encountered at any time during the various activities, all work in that location will immediately stop
2. The site will be stabilised if necessary
3. Contact to be made with RMMAC Chairperson and Berri Police
4. Location and detail of discovery to be recorded
5. Site rehabilitated under the guidance of RMMAC representatives

2. Excavation forms

a. Context record form—page 1.

Context Record

Trench Code:

Context ID:

Area or Quad (If applicable)

Date/time opened:

Recorder:
(1 person only)

Excavators:
(List all)

Sieve sizes used:
(list from coursest to finest):

1. __________mm
2. __________mm
3. __________mm
4. __________mm

Catch tray?
❒Y or ❒N

Excavation Units (XUs) Excavate all contexts in arbitrary spits. Complete a level form for each spit..

XU depth: ____________ mm

Notes:

Number of levels excavated: _______________

Pre-excavation recording tasks (Always complete all fields below before commencing excavation of a new context)

Scale Plan Drawn? Y ❒; Plan Number: ______________; Drawn by:____________________________________

Draw at 1:20 scale. Ensure trench,context and area details are noted.

Vertical photographs taken? Y ❒; Camera name:__________________; Image Nos:____________________

Include north arrow. Must be 'top down', full frame photo ideally with 50mm lens. Avoid flash photography. Also complete digital image pro-forma with each camera.

Photogrammetric photos taken? Y ❒; Camera name:_______________; Image Nos:____________________

Use a 50mm lens at a consistent distance of 2m from trench, taken diagonally from each corner and every 50cm along walls. Use manual settings where possible. Aim for an even distribution of consistent photographs around the trench boundary. Use camera stand ~50cm in height. Aim is to capture both floor and walls in 3D.

Other pre-excavation recording: ____

Context Starting levels. UTM GDA 94 Zone _____ or other:____________
(Record full extent of starting levels. Sketch point locations.).

Point No / X / Y / Z / Description:

MN.

Context type: ❒ Deposit ❒ Fill ❒ Cut ❒ Structural ❒ Other:____________________

Stratigraphic Matrix

						Above this context
This context						
						Below this context

Matrix notes:

b. Context record form—page 2.

Fill:
1. Compaction
2. Colour
3. Composition/Particle size (>10%)
4. Inclusions (<10%)
Occ ☐; Mod ☐ ; Freq ☐
5. Thickness and extent
6. Other comments
7. Method and conditions

Description
(See MOLAS guidelines)

Cut:
1. Shape in plan
2. Corners
3. Dimensions/depth
4. Break of slope (top)
5. Sides
6. Break of slope (bottom)
7. Base
8. Orientation
9. Inclination of axis
10. Truncated
11. Other comments.

Your interpretation/discussion:

Supplementary notes, plans , samples or data

Context closure checklist
(To be completed by trench supervisor):

Context metadata: ☐
Pre-excav. recording: ☐
Context description: ☐
Stratigraphic Matrix: ☐
Interp/discussion: ☐
Level forms attached: ☐
Trench form updated? ☐

Date/time closed:

c. Level recording form—page 1.

Level/XU Record

Trench Code:

ContextID:_________; Level number_________

Date/time context opened:

Recorder:
(1 person only)

Starting levels (Height ASL)

sketch relative positions and indicate north

Pt. ID;	Z	Pt. ID;	Z
______;	_____.___m;	______;	_____.___m;
______;	_____.___m;	______;	_____.___m;
______;	_____.___m;	______;	_____.___m;
______;	_____.___m;	______;	_____.___m;

Mean Starting Level: _____._______m ASL.

Mean End Level _____._______m ASL *(complete once new level opened)*

Mean XU Depth ___________ cm

MN.

Pre-excavation recording tasks (*Always complete all fields below before commencing excavation of a new context)*

Scale Plan Drawn? Y ☐ N ☐; Plan Number: _______________; Drawn by:______________________________

Draw at 1:20 scale. Ensure trench,context and area details are noted on plan if plan has been drawn already, or if there are no visible features, a plan is not required.

Vertical photographs taken? Y ☐; Camera name:____________________; Image Nos:_________________________

Include north arrow. Must be 'top down', full frame photo ideally with 50mm lens. Avoid flash photography. Also complete digital image pro-forma with each camera.

Sediment pH readings: *Take 1 reading near centre of each 50cm² square. Indicate loations on plan, above. Ensure instrument is inserted ≤ depth of spit.*

Number	*Area*	*pH*	*Number*	*Area*	*pH*	*Number*	*Area*	*pH*	*Number*	*Area*	*pH*	*Number*	*Area*	*pH*

Notes on excavation (e.g. difficulties, observations, methods. Record finds overleaf):

____

____

____

Gross Weight of Bulk residues (as excavated) (Include weight of bucket OR calibrate scales for bucket. Only use standard bucket for all weighing)

01: _____.____kg	05: _____.____kg	09: _____.____kg	13: _____.____kg	17: _____.____kg
02: _____.____kg	06: _____.____kg	10: _____.____kg	14: _____.____kg	18: _____.____kg
03: _____.____kg	07: _____.____kg	11: _____.____kg	15: _____.____kg	19: _____.____kg
04: _____.____kg	08: _____.____kg	12: _____.____kg	16: _____.____kg	20: _____.____kg

Gross Weight: _____.____kg.

Sieve size=________mm (Include weight of bucket OR calibrate scales for bucket. Only use standard bucket for all weighing)

01: _____.____kg	04: _____.____kg	07: _____.____kg	10: _____.____kg	13: _____.____kg
02: _____.____kg	05: _____.____kg	08: _____.____kg	11: _____.____kg	14: _____.____kg
03: _____.____kg	06: _____.____kg	09: _____.____kg	12: _____.____kg	15: _____.____kg

Gross Weight: _____.____kg.

Less Individual bucket weight: _____.____kg x _____ buckets = _____.____kg Net Weight: _____.____kg

Sampling Notes:____

Sample size	*Sample weight*	*No. of Bags*	*Sample ID numbers* (e.g. Trench 1, Context A-3, Sample Type, Bag Number)
______%	_____.____kg	______	____________________________

d. Level recording form—page 2.

Sieve size=________mm (Include weight of bucket OR calibrate scales for bucket. Only use standard bucket for all weighing)

01: _____._____kg 04: _____._____kg 07: _____._____kg 10: _____._____kg 13: _____._____kg

02: _____._____kg 05: _____._____kg 08: _____._____kg 11: _____._____kg 14: _____._____kg

03: _____._____kg 06: _____._____kg 09: _____._____kg 12: _____._____kg 15: _____._____kg

Gross Weight: _____._____kg.

Less Individual bucket weight: _____._____kg x _____ buckets = _____._____kg Net Weight: _____._____kg

Sampling Notes:________________________________

Sample size *Sample weight* *No. of Bags* *Sample ID numbers* (e.g. Trench 1, Context A-3, Sample Type, Bag Number)

______% _____._____kg ______ ________________________________

Sieve size=________mm (Include weight of bucket OR calibrate scales for bucket. Only use standard bucket for all weighing)

01: _____._____kg 04: _____._____kg 07: _____._____kg 10: _____._____kg 13: _____._____kg

02: _____._____kg 05: _____._____kg 08: _____._____kg 11: _____._____kg 14: _____._____kg

03: _____._____kg 06: _____._____kg 09: _____._____kg 12: _____._____kg 15: _____._____kg

Gross Weight: _____._____kg.

Less Individual bucket weight: _____._____kg x _____ buckets = _____._____kg Net Weight: _____._____kg

Sampling Notes:________________________________

Sample size *Sample weight* *No. of Bags* *Sample ID numbers* (e.g. Trench 1, Context A-3, Sample Type, Bag Number)

______% _____._____kg ______ ________________________________

Field quantification of repatriated materials

Please enter any supplementary data entry on Android Handset. Ensure materials are thoroughly hand sorted where bulk samples are being discarded.

Type: ________________; Number: _____; Diameter Max:_____Min:_____; Weight: _____._____kg

Type: ________________; Number: _____; Diameter Max:_____Min:_____; Weight: _____._____kg

Type: ________________; Number: _____; Diameter Max:_____Min:_____; Weight: _____._____kg

Type: ________________; Number: _____; Diameter Max:_____Min:_____; Weight: _____._____kg

In situ finds or samples (artefacts, C14 samples, etc, removed individually

Pt. ID Type/Description *Sample ID numbers* (e.g. Trench 1, Context A-3, Sample Type, Bag Number)

_____; ______________________; ______________________

_____; ______________________; ______________________

_____; ______________________; ______________________

_____; ______________________; ______________________

_____; ______________________; ______________________

_____; ______________________; ______________________

_____; ______________________; ______________________

_____; ______________________; ______________________

Supplementary notes, plans , samples or data

Context closure checklist

(To be completed by trench supervisor):

Metadata: ❐

Level data: ❐

Pre-excav. recording: ❐

Excavation data: ❐

Field quantification: ❐

Trench form updated: ❐

ENSURE ALL SAMPLES ARE DOUBLE TAGGED/ AND BAGGED BEFORE OPENING NEW LEVEL!

Date/time closed:

3. Data Plan

Data management Plan R. Jones Calperum 2019–2021

PROJECT OVERVIEW

Project title	Earth mound Study Calperum
College	CHASS
Discipline	Archaeology
Project type	PhD research project
Site name	Calperum
Site ID	CALP
Start date	March 2018
End date	March 2022
Funding sources	Flinders University, Australian Archaeological Association, Royal Society of South Australia
Activity type	Archaeological research
Description	Excavations are planned for September 2019 to April 2021
Keywords	

PEOPLE

Researcher	R. deWet-Jones
Email	Bob.dewet-Jones@flinders.edu.au
Data manager	Archaeology technical officers
Email	Arch.tech@flinders.edu.au
Principal supervisor	Professor Amy Roberts
Email	Amy.Roberts@flinders.edu.au
Associate supervisor	Assoc. Prof. Ian Moffat
Email	Ian.Moffat@flinders.edu.au

DATA STORAGE

Expected size of the data collected	10GB
Storage location	TBA
Location of master versions	TBA
Backed up	

ETHICS AND SENSITIVITIES

Ethics approval number	6618
Type of sensitivity	Moderate

OWNERSHIP, LICENSING AND IP

In which country is the data collected	Australia
Copyright and IP owners	Unspecified: Treating the collection as belonging to the Indigenous representatives referred to in permit
Any other owners	
Contractual obligations applying to this data	As per the permit
Permits	Excavation Permit: Authorisation letter B423901 dated: 11/09/2019

ABOUT THE DATA

File formats used	Exists in hard copy, digitised to NAA standard .pdf, .jpg
Software versions used	N/A
Any special hardware or software requirements?	No
Non-digital data	Original hard copies will be retained to provide a back-up of the original data.
Metadata	Descriptive metadata for this dataset includes title, author/researchers, description, keywords, file descriptions, dates
Identifiers	Identified by code CALPRJ
File naming	The file naming convention for the boxes follow`s as CALPRJ01, CALPRJ 02, CALPRJ 03 etc. The file naming for the samples is not systematic, it roughly follows with: Site identifier EM followed by a unique identifier; The flotation material has an unassociated naming convention.

Archaeological collection	
	Box: CALPRJ 01 Site Plans; Field and general notes; Survey and excavation recording forms; Photograph recording forms Box: CALPRJ 02 Surface samples; Sediment and charcoal samples; Artefacts; Faunal material; Unidentified materials. Box: CALPRJ 03 Surface samples; Sediment and charcoal samples; Artefacts; Faunal material; Un-identified materials; Floatation materials Box: CALPRJ 04 Surface samples; Sediment and charcoal samples; Artefacts; Faunal material; Un-identified materials Box: CALPRJ 05 Surface samples; Sediment and charcoal samples; Artefacts; Faunal material; Un-identified materials

DATA LICENSING AND ACCESS

Access will be managed by	Unspecified: Currently cared for by the Flinders University Archaeology Department Technical Officers
Access via a repository or archive	Unspecified: Currently held by the Flinders University Archaeology Department under restricted access.
Copies of the data	Unspecified: Currently held by the Flinders University Archaeology Department under restricted access.

DATA RETENTION AND DISPOSAL

Electronic data	Unspecified
Physical data e. g. field notes	Unspecified
Artefacts	As per authorisations listed in the authorisation letter dated 19/09/2019. Following the completion of the excavation and analysis of the excavation material, the material is to be under the care of the Indigenous representatives.

Appendix Eight: Double Thookle Billabong Mound Contexts and Associated Surface Artefacts

1. **Views from the centre of the dry billabong surface in April 2019.**

Figure 8A.1: View to the east taken from the centre of Double Thookle Billabong (location of mounds HIS_2_21, HIS_2_22 and HIS_2_23. Photograph R. Jones April 2019.

Figure 8A.2: View to the west taken from the centre of Double Thookle Billabong. Photograph R. Jones April 2019.

Figure 8A.3: View to the southwest taken from the centre of Double Thookle Billabong, Mound HIS_2_23 is located to the left of the photograph. Photograph R. Jones April 2019.

Figure 8A.4: View to the north taken from the centre of Double Thookle Billabong, Mound HIS_2_21 is located behind the low foliage shown in the photograph. Photograph R. Jones April 2019.

Figure 8A.5: View to the southeast taken from the centre of Double Thookle Billabong, Mound HIS_2_22 is located behind the tree line shown in the photograph. Photograph R. Jones April 2019.

2. **Photographs of a sample of stone artefact types recorded from the surrounding areas of the mounds excavated at Double Thookle Billabong. Photographs Matthew Bowden April 2019.**

Figure 8A.6: Quartzite/silcrete fragment.

Figure 8A.7: Chert fragment.

Figure 8A.8: Chert fragment.

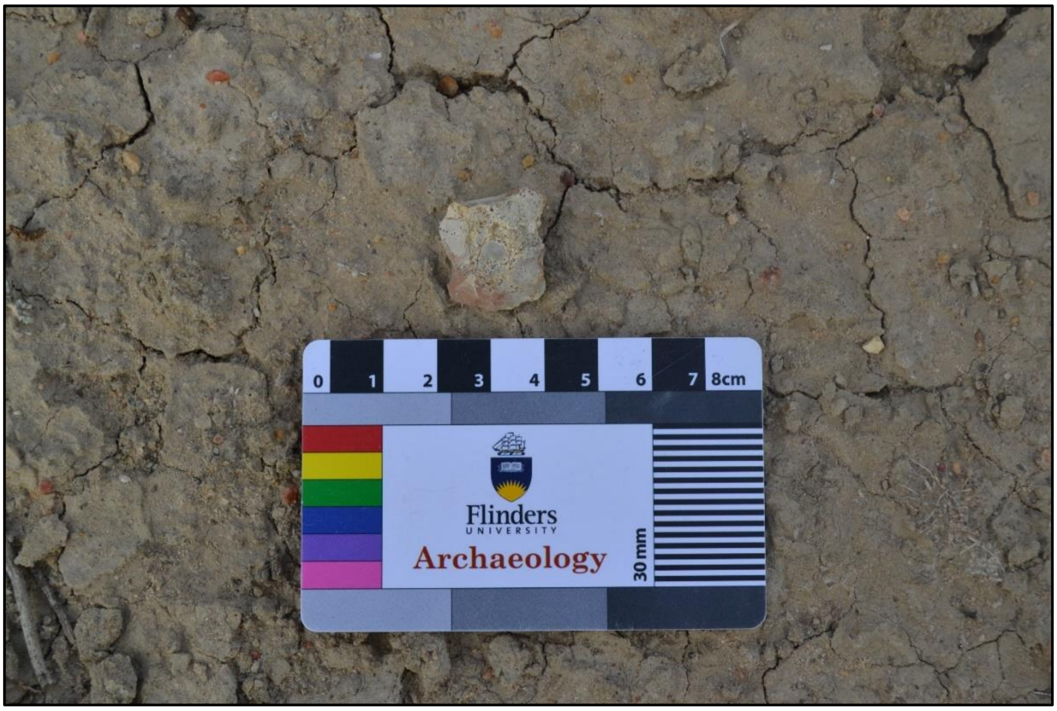


Figure 8A.9: Chert fragment.

Figure 8A.10: Silcrete/quartzite and chert fragments.

Figure 8A.11: Reverse image of quartzite/silcrete and chert flakes above.

Figure 8A.12: Quartzite/silcrete fragment.

Figure 8A.13: Reverse image of quartzite/silcrete fragment.

Figure 8A.14: Chert flake.

Figure 8A.15: Chert flake.

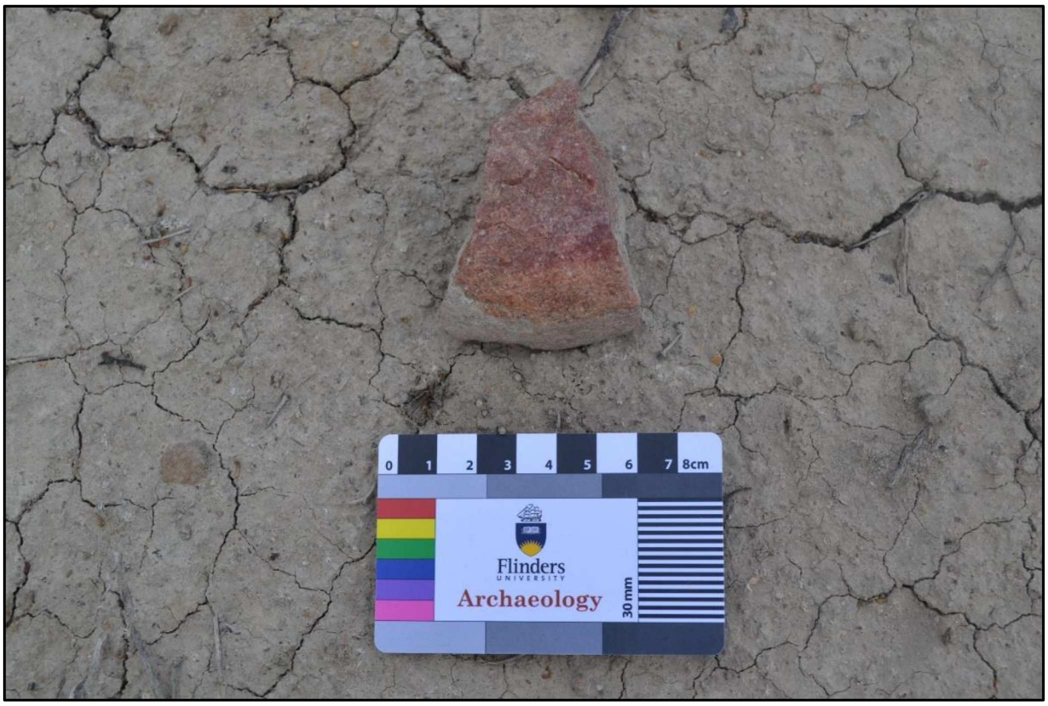


Figure 8A.16: Quartzite/silcrete fragment.

Figure 8A.17: Quartzite/silcrete fragment.

Figure 8A.18: Tula style oblique scraper.

Figure 8A.19: Reverse image tula style scraper above

.

Figure 8A.20: Fragment of quartzite/silcrete showing evidence of burning.

Figure 8A.21: Possible fragment of grinding stone—front and reverse images.

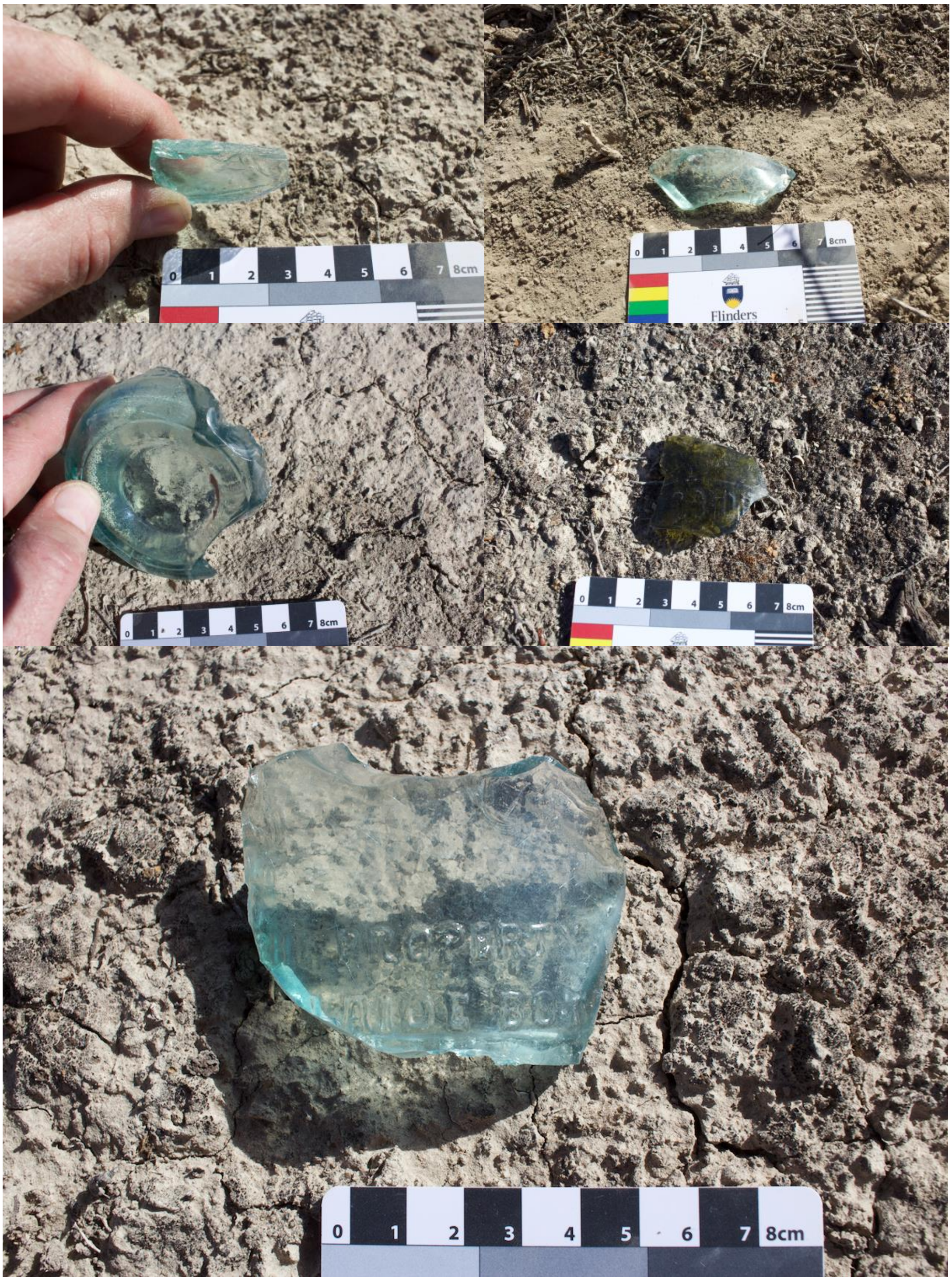


Figure 8A.25: Glass artefacts possibly worked and used from south of mound HIS_2_22.

3. Artefact data

Table 8A.1: Detail of artefacts recorded from areas surrounding mound HIS_2_21.

Site	Material	Type	Colour	Termination	Scars	Cortex	Length mm	Width mm	Depth mm	Notes
HIS_2_21	Chert	proximal flake	pink-white			0-25%	24	17	9	
	crystal quartz	broken flake	clear				17	13	6	brown Inclusions. no landmarks
	sandstone	thin plate	pink				86	69	6	
	silcrete	broken flake	pink-brown				17	20	6	
	sandstone	fragment	dark grey				30	22	17	no landmarks, fine grained
	chert	flake fragment	dark red	hinge			12	13	3	longitudinal break
	chert	broken flake	dark red			0-25%	16	11	4	
	silcrete	flake	dark red/ brown				20	17	2	
	chert	flake	light brown				19	16	8	medial break
	chert	small flake	orange red				13	6	3	
	sandstone	fragment	beige				25	25	15	one smoother surface
	chert	flake	white / pink		1		17	8	5	medial break
	chert	angular fragment	grey				17	21	6	
	chert	angular fragment	red brown				19	10	4	
	sandstone	fragment	grey				34	25	25	possible heat damage, possibly grindstone
	chert	angular fragment	brown				19	8	4	
	chert	flake	grey		2		11	9	4	
	silcrete	small core	brown		2	25-50%	22	16	9	
	chert	flake	brown white			0-25%	13	17	6	naturally backed small flake
	chert	tula oblique scraper	cream		use damage		13	31	10	platform 24x7mm,
	silcrete	Fragment	red				25	21	13	no landmarks

Table 8A.2: Detail of artefacts recorded from areas surrounding mound HIS_2_22.

Site	Material	Type	Colour	Termination	Scars	Cortex	Length mm	Width mm	Depth mm	Notes
HIS_2_22	Glass	body sherd	dark green				35	42	4	Wording: CO OP
	Glass	body sherd	aqua		Use damage		34	33	7	
	Glass	body sherd	aqua		2		58	23	7.5	
	Glass	body sherd	aqua				49	28	10	Wording: Indistinct lettering
	Glass	body sherd	aqua				42	37	14	
	Glass	body sherd	aqua		2 areas edge modified		70	52	7	Wording: Property Adelaide Bottling Company
	Glass	cluster of sherds (8)	dark green							
	chert	broken flake	brown / faun		retouched dentate		23	24	6	
	glass	body sherd	dark green		possible retouch		38	28	5	
	glass	body sherd	dark green		no retouch		41	35	6	
	glass	body sherd	clear				35	27	5.5	
	glass	body sherd	aqua				44	30	5.5	
	glass	body sherd	dark green				47	28	4	
	glass	body sherd	aqua				62	26	5.5	modified, shaped to point, sharpened edges
	quartzite	angular fragment					22	15	5	
	Quartzite	Fragment	purple				41	36	17	no usewear
	quartzite	fragment	white				34	26	20	no usewear
	quartzite	Fragment					31	21	15	no usewear
	Quartzite	Fragment					43	29	24	possible grindstone fragment
	sandstone	fragment					38	38	35	no usewear
	chert	core			2	0	28	20	12	Crushed platform
	chert	angular fragment	light faun/brown				32	18	6	
	quartzite	fragment	grey				26	28	12	no usewear
	quartzite	fragment	pink-grey				53	42	24	possibly heat effected
	quartzite	Fragment	white - red				43	36	22	no usewear

Table 8A.3: Detail of artefacts recorded from areas surrounding mound HIS_2_23.

Site	Material	Type	Colour	Termination	Scars	Cortex	Length mm	Width mm	Depth mm	Notes
HIS_2_23	Chert	Complete Flake					42	22	6.5	
	Chert	Core			3	1-50%	30	27	18	
	sandstone	Fragment	Pink/grey				34	29	22	Portion large flat slab
	Chert	small core	Red/brown		1		37	19	14	
	sandstone	nodule	red/pink				37	25	16	coarse
	Chert	Flake	caramel	feather		0%	27	26	9	retouch /backing opposite blade
	Quartzite	angular fragment	pinkish white				28	27	13	
	Chert	angular fragment	red orange				15	13	5	
	Glass	Body sherd	clear		edge / use damage		63	53	7	
	silcrete	core	red		2		34	30	16	
	sandstone	fragment	dark grey				44	29	25	Coarse
	chert	broken flake	reddish brow				12	10	2	
	chert	flake	White-orange	feather	edge damage	0	27	16	8	Longitudinal break. Flat, broken
	chert	broken flake	Whit- orange	Indet.		0	19	10	4	
	Glass	Bottle base	aqua		distal flake scar		80	80		Wording: PANY LTD Adelaide
	quartzite	angular fragment					28	20	8	Eastern side of depression
	chert	medial flake	red / white				28	20	10	
	quartzite	Fragment	red				30	30	15	no landmarks
	chert	flake	white				29	18	11	split longitudinally
	quartzite	Fragment	white				40	36	19	possible burning, possible grindstone frag
	quartzite	angular fragment	orange				43	27	22	
	Chert	flake	White-brown	step			21	28	9	proximal flake
	quartzite	Complete Flake		feather			46	27	9	
	chert	angular fragment	white				22	19	10	

Table 8A.3: Continued.

HIS_2_23	quartzite	angular fragment	brown				35	12	8	
	chert	distal flake	white				22	15	7	
	chert	medial flake	brown				20	14	4	
	chert	Complete Flake	brown				27	19	5	
	chert	proximal flake					19	15	7	
	chert	proximal flake	Brown-white				26	22	12	
	chert	Complete Flake	orange				23	12	5	
	chert	angular fragment	white				15	13	8	
	sandstone	muller fragment	beige				39	17	17	one rounded surface
	quartzite	distal flake	brown				32	35	13	
	chert	medial flake	red brown				13	20	3	
	chert	angular fragment	brown				24	24	16	
	sandstone	Fragment	white				37	28	26	
	chert	Complete Flake	brown				17	21	10	
	quartzite	Complete Flake					26	20	13	
	chert	flake	light orange				19	26	8	split longitudinally
	chert	Complete Flake	Orange-white				13	12	3	
	quartzite	angular fragment	red				41	37	25	possible burning
	quartzite	angular fragment	brown				19	17	10	
	chert	Complete Flake	light orange	axial			16	18	4	
	quartzite	angular fragment	white				43	41	27	
	chert	Complete Flake	red				29	16	7	
	chert	angular fragment	red				15	13	13	
	sandstone	angular fragment	beige				43	29	15	
	chert	flake	red / white				22	10	9	
	chert	proximal flake	brown				16	30	10	
	chert	Complete Flake	white / brown				12	14	4	
	chert	flake	faun				24	14	6	longitudinal split

Table 8A.3: Continued.

HIS_2_23	sandstone	nodule	white-red				17	19	5	
	chert	Complete Flake	red				23	41	10	
	quartzite	Complete Flake	red				22	23	6	

Appendix Nine: Previously Published Radiocarbon Dates for Australian Earth Mounds

Calibrations made withOxCal (version 4.4) (Bronk Ramsey 2009), using the SHcal20 (Hogg et al. 2020) and marine 20 curves where appropriate (Reimer et al. 2020).

Table 9A.1: Calibrated ^{14}C ages for western Victoria.

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
4/1	Caramut	ANU-3885	Charcoal	360	280	760	740	750	Williams 1988:84
6/1	Caramut	ANU-3881	Charcoal	Modern					Williams 1988:91
6/2B	Caramut	ANU-3761	Charcoal	440	70	536	311	424	Williams 1988:93
6/2B	Caramut	ANU-3585	Charcoal	760	100	900	525	713	Williams 1988:93
6/2C	Caramut	ANU-3887	Charcoal	1580	240	1998	960	1479	Williams 1988:93
6/3	Caramut	ANU-3586	Charcoal	2030	120	2312	1615	1964	Williams 1989
C/2	W. Victoria	SUA-571	Charcoal	1320	100	1351	962	1157	Coutts et al.1977
C/3	W. Victoria	SUA-537	Charcoal	1840	100	1996	1485	1741	Coutts et al.1977
CH/1	W. Victoria	SUA-778	Charcoal	995	100	1057	678	868	Coutts et al.1978
FM/1	W. Victoria	SUA-574	Charcoal	2350	110	2716	2090	2403	Coutts et al.1977
KP/1	W. Victoria	SUA-672	Charcoal	1420	100	1514	1065	1290	Coutts et al.1977
M 33	Caramut	ANU-4322	Charcoal	300	60	492	141	317	Williams 1988
MCC 5	Caramut	ANU-3762	Charcoal	790	190	1173	330	752	Williams 1988
MCC6	Caramut	ANU-3888	Charcoal	1870	130	2055	1428	1742	Williams 1988
MM2	Montrose	ANU-3759	Charcoal	410	100	557	146	352	Williams 1988:156
MM2	Montrose	ANU-3757	Charcoal	1600	220	1995	989	1492	Williams 1988:156
MM1	Montrose	ANU-3758	Charcoal	1270	100	1305	935	1120	Williams 1988

Table 9A.2: Calibrated ^{14}C ages for the central Murray region.

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
Munroes Plain 1	Goulb. River	Beta-63813	Charcoal	180	50	282	158	220	Godfrey et al. 1996
Munroes Plain 1	Goulb. River	Beta-63812	Charcoal	320	70	500	141	321	Godfrey et al. 1996
Boort swamp	Lake Boort	Wk-11144	Charcoal	187	49	285	0	143	Johnston 2004
Boort swamp	Lake Boort	Wk-11146	Charcoal	187	50	285	0	143	Johnston 2004
Boort swamp	Lake Boort	Wk-11147	Charcoal	261	47	444	0	222	Johnston 2004
Boort swamp	Lake Boort	Wk-11145	Charcoal	775	47	735	563	649	Johnston 2004
Boort swamp	Lake Boort	Wk-11148	Charcoal	984	48	930	739	835	Johnston, 2004
Boort swamp	Lake Boort	Wk-11149	Charcoal	2059	46	2093	1840	1967	Johnston, 2004

Table 9A.3: Calibrated ^{14}C ages for north western Murray region (Swan Hill).

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
DP/1 (75271/003)	Nyah	SUA-1929	Charcoal	1030	60	1048	744	896	Godfrey et al. 1996
DP/1 (75271/003)	Nyah	SUA-1242	Charcoal	730	80	762	535	649	Godfrey et al. 1996
DP/1 (75271/003)	Nyah	SUA-996	Charcoal	960	80	958	680	819	Coutts et al. 1979; Coutts 1980
DP/1 (75271/003)	Nyah	SUA-999	Charcoal	1200	80	1269	926	1098	Coutts et al. 1979; Coutts 1980
DP/1 (75271/003)	Nyah	SUA-998	Charcoal	1245	80	1274	960	1117	Coutts et al. 1979; Coutts 1980
DP/1 (75271/003)	Nyah	SUA-997	Charcoal	1375	130	1514	961	1238	Coutts et al. 1979; Coutts, 1980
DP/2	Nyah	SUA-1117	Charcoal	800	100	905	550	728	Godfrey et al. 1996
DP/2	Nyah	SUA-1927	Charcoal	1250	60	1270	964	1117	Godfrey et al. 1996
DP/2	Nyah	SUA-1928	Charcoal	1390	60	1363	1099	1231	Godfrey et al. 1996
DP/2	Nyah	SUA-1118	Charcoal	1610	90	1696	1303	1500	Godfrey et al. 1996
DP/5	Nyah	SUA-1128	Charcoal	250	80	447	0	224	Godfrey et al. 1996
DP/5	Nyah	SUA-1119	Charcoal	1470	90	1535	1117	1326	Godfrey et al. 1996
DP/6	Nyah	SUA-1916	Charcoal	950	80	957	679	818	Godfrey et al. 1996
DP/6	Nyah	SUA-1930	Charcoal	1000	80	1051	687	869	Godfrey et al. 1996
DP/7	Nyah	SUA-1120	Charcoal	1180	150	1310	741	1026	Godfrey et al. 1996
DP/8	Nyah	SUA-1917	Charcoal	260	70	450	0	225	Godfrey et al. 1996
DP/8	Nyah	SUA-1241	Charcoal	1000	90	1055	682	869	Godfrey et al. 1996

Table 9A.4: Calibrated ^{14}C ages for the Gillman mound (northern Adelaide).

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
Gillman mound	Nth Adel. Pl.	NZA-35253	Burnt soil	367	15	454	318	386	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-35329	Bone	492	25	535	470	503	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-35746	Bone	760	30	723	700	712	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-35639	Bone	781	25	725	577	651	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-38041	Bone	793	15	724	661	693	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-35561	Bone	891	15	793	725	759	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-35555	Bone	895	15	792	727	760	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-35819	Bone	1106	15	1046	926	986	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-35556	Bone	1121	20	1054	929	992	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-35562	Bone	1774	20	1701	1588	1645	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-35232	Shell	2486	15	2281	1899	2090	Littleton et al. 2013
Gillman mound	Nth Adel. Pl.	NZA-38322	Burnt Clay	10468	35	12596	12095	12346	Littleton et al. 2013 (discounted—under mound sediments)

Table 9A.5: Calibrated ^{14}C ages for the Murrumbidgee Region.

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
CC31/1	Murrumbid.	ANU-8610	Charcoal	2520	70	2730	2359	2545	Klaver 1998
CC36/lev 2/d	Murrumbid.	ANU-7880	Charcoal	2890	90	3219	2764	2992	Klaver 1998
CC36/lev 4	Murrumbid.	ANU-7879	Charcoal	2720	90	3060	2494	2777	Klaver 1998
CC5/lev 1	Murrumbid.	ANU-7881	Charcoal	2940	170	3481	2724	3103	Klaver 1998
CP116/D3/3	Murrumbid.	ANU-8613	Charcoal	740	60	726	556	641	Klaver 1998
CP116/D4/ 9	Murrumbid.	ANU-8612	Charcoal	970	50	926	738	832	Klaver 1998
CP116/D4/11/12	Murrumbid.	ANU-8603	Charcoal	970	70	958	688	823	Klaver 1998
CP116/D4/5	Murrumbid.	ANU-8614	Charcoal	550	50	632	489	561	Klaver 1998
CP116/D4/6	Murrumbid.	ANU-8615	Charcoal	530	70	650	327	489	Klaver 1998
CP116/D4/7	Murrumbid.	ANU-8616	Charcoal	450	60	534	322	428	Klaver 1998
CP16/D3/8	Murrumbid.	ANU-8611	Charcoal	500	70	629	323	476	Klaver 1998
CP59/4/a	Murrumbid.	ANU-8608	Charcoal	440	70	536	311	424	Klaver 1998
CP59/4/b	Murrumbid.	ANU-8609	Charcoal	650	70	671	514	593	Klaver 1998
CP79/3/A	Murrumbid.	ANU-8604	Charcoal	750	60	731	556	644	Klaver 1998
CP79/3/B	Murrumbid.	ANU-8605	Charcoal	680	60	676	534	605	Klaver 1998
CP82/3BB/1-2/H	Murrumbid.	ANU-8617	Charcoal	420	70	525	303	414	Klaver 1998
CP82/3BB/6/K	Murrumbid.	ANU-8619	Charcoal	2660	70	2924	2468	2696	Klaver 1998
CP82/3BB/7/J	Murrumbid.	ANU-8618	Charcoal	640	60	663	520	592	Klaver 1998
CP82/4/1-2/D	Murrumbid.	ANU-8623	Charcoal	390	70	516	285	401	Klaver 1998
CP82/4/1-2-3/C	Murrumbid.	ANU-8622	Charcoal	960	170	1179	557	868	Klaver 1998
CP82/4/4-1/A	Murrumbid.	ANU-8620	Charcoal	390	60	503	302	403	Klaver 1998
CP82/4/6/E	Murrumbid.	ANU-8624	Charcoal	650	60	665	525	595	Klaver 1998
CP82/6D/2/G	Murrumbid.	ANU-8626	Charcoal	490	60	622	324	473	Klaver 1998
CP82/6D/7/F	Murrumbid.	ANU-8625	Charcoal	640	60	663	520	592	Klaver 1998

Table 9A.6: Calibrated ^{14}C ages for the Macquarie Marsh region.

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
Macquarie Marsh	Macquarie	SUA-2892	Charcoal	1050	90	1176	727	952	Balme and Beck 1996

Table 9A.7: Calibrated ^{14}C ages for the Wakool area of southern New South Wales (Central Murray Region).

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
Q7	Wakool	Beta-7065	Charcoal	2250	105	2668	1927	2298	Berryman and Frankel 1984
M1	Wakool	Beta-7067	Charcoal	2490	60	2716	2356	2536	Berryman and Frankel 1984
F3	Wakool	Beta-7068	Charcoal	2990	100	3366	2862	3114	Berryman and Frankel 1984

Table 9A.8: Calibrated ^{14}C ages for the western Hay Plain (near Balranald).

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
Tchelery1	Hay Plain	Wk-17491	Bone AMS	3947	39	4512	4158	4335	Martin 2006
Tchelery1	Hay Plain	Wk-4095	Bone AMS	3730	240	4807	3454	4131	Martin 2006
Tchelery1	Hay Plain	Wk-4096	Charcoal	3721	75	4287	3774	4031	Martin 2006
Tchelery1	Hay Plain	Wk-4097	Charcoal	3990	230	5045	3723	4384	Martin 2006
Tchelery1	Hay Plain	Wk-4098	Charcoal	3570	100	4143	3497	3820	Martin 2006
Tchelery1	Hay Plain	Wk-4100	Charcoal	3760	210	4800	3495	4148	Martin 2006
Tchelery1	Hay Plain	Wk-4099	Ash	4010	170	4861	3930	4396	Martin 2006
Tchelery1	Hay Plain	Wk-4101	Charcoal	4340	160	5319	4425	4872	Martin 2006
Ravensworth 3	Hay Plain	Wk-17504	Bone AMS	3820	36	4351	3986	4169	Martin 2006
Ravensworth 3	Hay Plain	Wk-17490	Bone AMS	3923	37	4420	4154	4287	Martin 2006
Ravensworth 3	Hay Plain	Wk-17503	Charcoal	4124	68	4823	4422	4623	Martin 2006
Ravensworth 3	Hay Plain	Wk-17502	Charcoal	4057	45	4800	4301	4551	Martin 2006
Ravensworth 3	Hay Plain	Wk-17501	Charcoal	4151	65	4833	4440	4637	Martin 2006
Ravensworth 3	Hay Plain	Wk-17489	Charcoal	4109	55	4817	4420	4619	Martin 2006
Ravensworth 3	Hay Plain	Wk-7500	Charcoal	3860	60	4415	3998	4207	Martin 2006
Ravensworth 3	Hay Plain	Wk-7501	Charcoal	4100	70	4827	4411	4619	Martin 2006
Ravensworth 3	Hay Plain	Wk-7502	Charcoal	3890	60	4425	4014	4220	Martin 2006

Table 9A.9: Calibrated ^{14}C ages for the Darwin coastal area.

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
H197 (CE)	Hope inlet	Wk-6526	*Andara* spp.	1830	100	1580	1064	1322	Brockwell 2006b; Bourke 2000
HI97	Coastal	OZI-896	Charcoal	1345	45	1303	1090	1197	Brockwell et al., 2009
HI97	Hope Inlet	OZI-286	*A. granosa*	1800	40	1460	1118	1289	Brockwell et al., 2009
MP (Middle Point)	Coastal	Wk-5581	Charcoal	350	70	502	151	327	Brockwell 2006a, 2006b, 2009
MP (Middle Point)	Coastal	Wk-8452	Charcoal	460	130	662	144	403	Brockwell 2006a, 2006b, 2010
MP (Middle Point)	Coastal	Wk-7400	Charcoal	630	60	660	515	588	Brockwell 2006a, 2006b, 2011
MP (Middle Point)	Coastal	Wk-6668	Bone	434	56	520	320	420	Brockwell 2006a, 2006b, 2009
MP (Middle Point)	Coastal	Wk-6669	Bone	1432	56	1403	1177	1290	Brockwell and Ackermann 2007

Table 9A.10: Calibrated ^{14}C ages for the Blyth River area, Northern Territory.

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
Ji-bena 1	Blyth R.	ANU-3415	*D. juvenilis*	970	80	703	264	484	Brockwell et al. 2005, 2009
Ji-bena 1	Blyth R.	ANU-3414	*D. juvenilis*	1250	80	973	508	741	Brockwell 2006b; Brockwell et al., 2009
Ji-bena 1	Blyth R.	ANU-3416	*D. juvenilis*	1260	70	964	524	744	Brockwell et al, 2005, 2009; Brockwell, 2006b
Ji-bena 1	Blyth R.	ANU-3417	*D. juvenilis*	1360	70	1100	616	858	Brockwell et al, 2005, 2009; Brockwell, 2006b
Ji-bena 1	Blyth R.	ANU-2817	*D. juvenilis*	1510	100	1269	714	992	Brockwell 2006a, 2006b; Brockwell et al, 2005
MP2/13	Adel. R.	Wk5582	Charcoal	1880	210	2315	1314	1815	Brockwell 2001b
NP20	Adel. R.	Wk-5580	Estur. Shell	Modern					Brockwell 2001b

Table 9A.11: Calibrated ^{14}C ages for the South Alligator River area, Northern Territory.

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
Kina (FW)	Sth. Alligator	ANU-3212	Charcoal	280	40	444	145	295	Brockwell 2006b; Meehan et al. 1985
J (CE)	Sth. Alligator	ANU-4047	Shell	1950	100	1774	1100	1437	Brockwell 2006b; Woodroofe et al. 1987
G (CE)	Sth. Alligator	ANU-3994	Shell	2080	70	1853	1315	1584	Brockwell 2006; Woodroofe et al. 1987
N (CE)	Sth. Alligator	ANU-4045	Shell	3050	70	3078	2464	2771	Brockwell 2006b; Woodroofe et al. 1987
H (CE)	Sth. Alligator	ANU-3991	Shell	4170	100	4543	3815	4179	Brockwell 2006b; Woodroofe et al. 1987
H (CE)	Sth. Alligator	ANU-3992	Shell	4600	80	5054	4390	4722	Brockwell 2006b; Woodroofe et al. 1987
38 (CE)	Mary R.	ANU-2887	Shell	Modern					Brockwell 2006b; Baker 1981
40 (CE)	Mary R.	ANU-2888	Shell	920	90	672	178	425	Brockwell 2006b; Baker 1981

Table 9A.12: Calibrated ^{14}C ages for the Reynolds River area, Northern Territory.

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
Djingurr 1 (FW)	Reynolds R.	Wk-7171	Charcoal	197	57	295	0	148	Brockwell 2006a; 2006b, 2009, Guse 2006,
Djingurr 1 (FW)	Reynolds R.	Wk-7431	Charcoal	400	60	505	305	405	Brockwell 2006a; 2006b, 2009, Guse 2006,
Pandyal 2 (FW)	Reynolds R.	Wk-7262	Charcoal	626	77	670	500	585	Brockwell 2006b; Guse 2006
Werat 14 (CE)	Reynolds R.	Wk-7170	*Andara spp.*	3480	50	3553	3020	3287	Brockwell 2006b; Guse 2006
Werat 1 (CE)	Reynolds R.	Wk-7432	*Andara spp.*	4330	50	4685	4093	4389	Brockwell 2006b; Guse 2006

Table 9A.13: Calibrated ^{14}C ages for the Weipa area, Northern Cape York, Queensland.

Site code	Region	Lab Code	Material	Age uncalib. BP	Error +/-	Cal 20 BP range upper	Cal 20 BP range lower	Cal BP median 95.4%	Source
EM101	East	Wk-33874	Charcoal	837	25	761	670	716	Brockwell et al. 2017
EM107	East	Wk-33872	Charcoal	951	28	908	739	824	Brockwell et al. 2017
EM117	Central	Wk-35012	Charcoal	128	25	253	0	127	Brockwell et al. 2017
EM119	Central	Wk-33871	Charcoal	163	25	274	0	137	Brockwell et al. 2017
EM10	Diingwulung	Wk-41146	Charcoal	134	20	253	0	127	Brockwell et al. 2017
EM20	Diingwulung	Wk-21003	*G. erosa*	237	47	138	0	69	Brockwell et al. 2017
EM21	Diingwulung	Wk-21004	*G.erosa*	285	35	144	0	72	Brockwell et al. 2017
EM22	Diingwulung	Wk-21005	*G.erosa*	391	44	212	0	106	Brockwell et al. 2017
EM22	Diingwulung	Wk-21006	*G.erosa*	446	43	233	0	117	Brockwell et al. 2017
EM24	Diingwulung	Wk-21007	*G.erosa*	331	44	184	0	92	Brockwell et al. 2017
EM24	Diingwulung	Wk-21009	*G.erosa*	356	35	192	0	96	Brockwell et al. 2017
EM24	Diingwulung	Wk-21008	*G.erosa*	460	35	235	0	118	Brockwell et al. 2017
EM28	Diingwulung	Wk-21011	*G.erosa*	229	46	135	0	68	Brockwell et al. 2017
EM28	Diingwulung	Wk-21010	*G.erosa*	365	35	193	0	97	Brockwell et al. 2017
EM30	Diingwulung	Wk-21012	*G. erosa*	226	37	127	0	64	Brockwell et al. 2017
EM36	Diingwulung	Wk-41147	Charcoal	183	31	282	0	141	Brockwell et al. 2017
EM54	Diingwulung	Wk-41148	Charcoal	115	20	252	0	126	Brockwell et al. 2017
EM33	West	WK-25932 C	Charcoal	139	30	262	0	131	Brockwell et al. 2017
EM33	West	Wk-25938	Charcoal	195	30	285	0	143	Brockwell et al. 2017
EM33	West	Wk-25936	Charcoal	307	30	446	156	301	Brockwell et al. 2017
EM33	West	Wk-25934	Charcoal	132	30	257	0	129	Brockwell et al. 2017
EM34	West	Wk-25935	*T. granosa*	333	40	183	0	92	Brockwell et al. 2017
EM34	West	Wk-37237	*T. granosa*	410	30	212	0	106	Brockwell et al. 2017
EM34	West	Wk-37238	*T. granosa*	448	31	229	0	115	Brockwell et al. 2017
EM34	West	Wk-25939	Charcoal	482	30	533	340	437	Brockwell et al. 2017
EM34	West	Wk-25933	*T. granosa*	487	34	246	0	123	Brockwell et al. 2017
EM34	West	Wk-25931	*T. granosa*	566	34	294	0	147	Brockwell et al. 2017
EM34	West	Wk-25939	*T. granosa*	578	34	307	0	154	Brockwell et al. 2017
SM52	West	Wk-36513	*T. granosa*	1014	28	701	382	542	Brockwell et al. 2017
SM52	West	Wk-36514	*T. granosa*	1177	25	860	522	691	Brockwell et al. 2017
SM52	West	Wk-36511	*T. granosa*	1618	26	1290	935	1113	Brockwell et al. 2017
SM62	West	Wk-37240	*T. granosa*	1662	34	1336	965	1151	Brockwell et al. 2017
SM62	West	Wk-37239	*T. granosa*	1701	32	1379	1002	1191	Brockwell et al. 2017
SM62	West	Wk-36510	*T. granosa*	1996	29	1706	1308	1507	Brockwell et al. 2017
SM62	West	Wk-36515	Charcoal	2040	32	2040	1840	1940	Brockwell et al. 2017
SM81	West	Wk-36512	Charcoal	2105	32	2109	1928	2019	Brockwell et al. 2017
SM81	West	Wk-41142	*G. erosa*	2280	34	2091	1619	1855	Brockwell et al. 2017
SM81	West	Wk-36516	*T. granosa*	3260	25	3291	2822	3057	Brockwell et al. 2017

Appendix Ten: Aerial Photographs of Mounds HCN21, HIS_2_21, HIS_2_22, HIS_2_23 and RRWWS3

Figure 10A.1: Mound HCN21. Hunchee Lagoon bottom right toward the southeast.

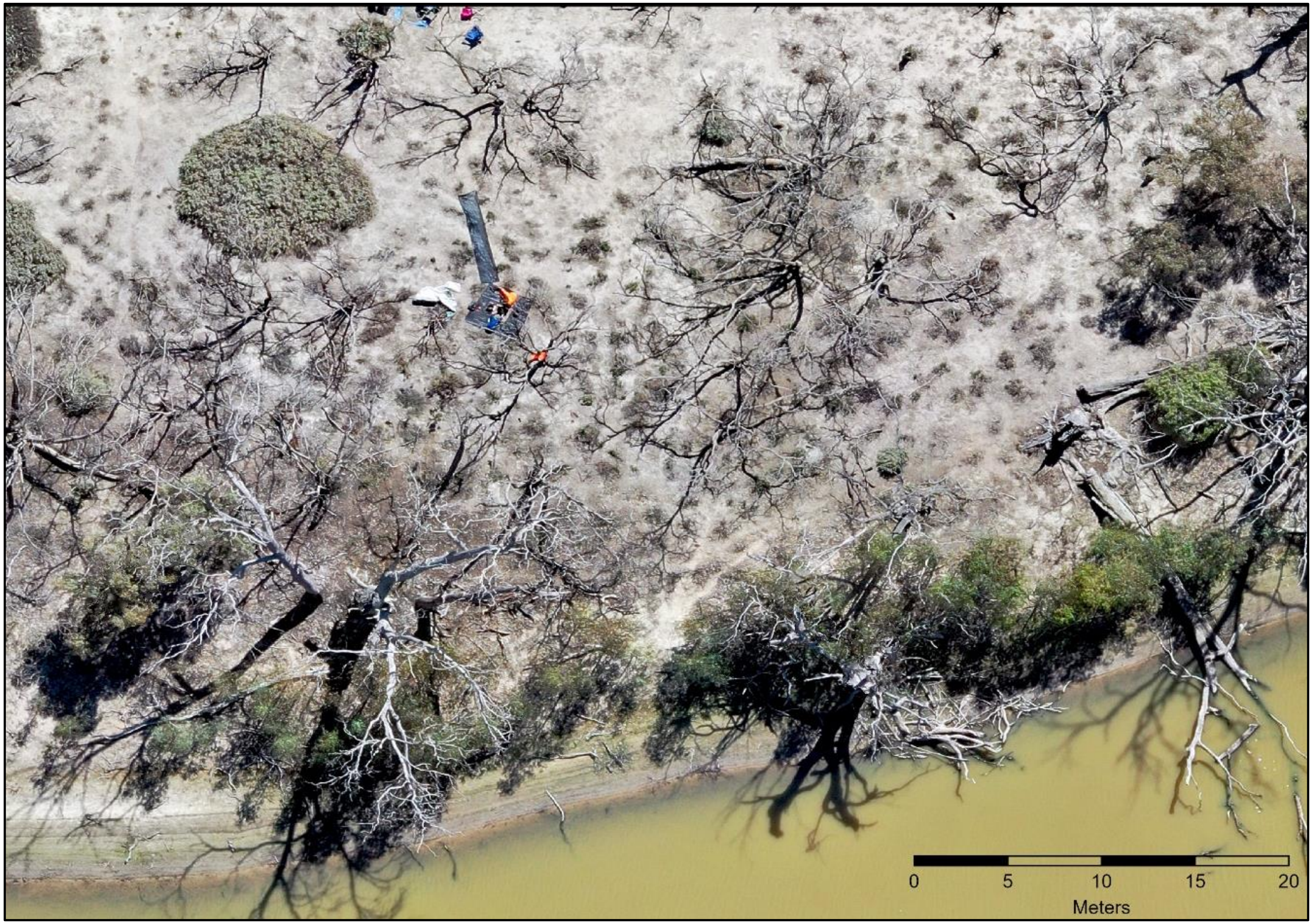


Figure 10A.2: Mound HIS_2_21 during excavation. Double Thookle Billabong at the bottom (south) bottom of the photograph.

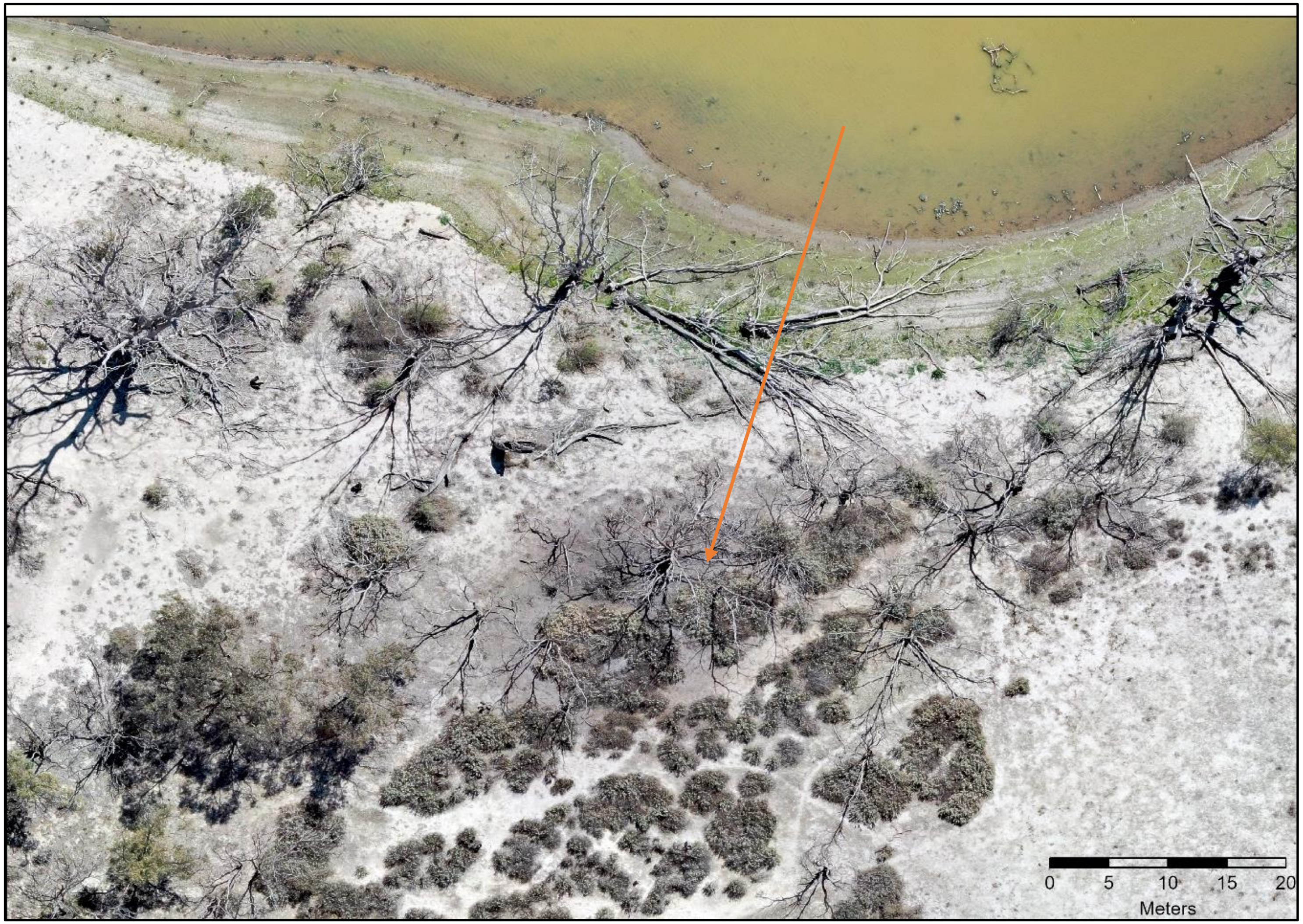


Figure 10A.3: Mound HIS_2_22. Double Thookle Billabong at the top (north) of the photograph.

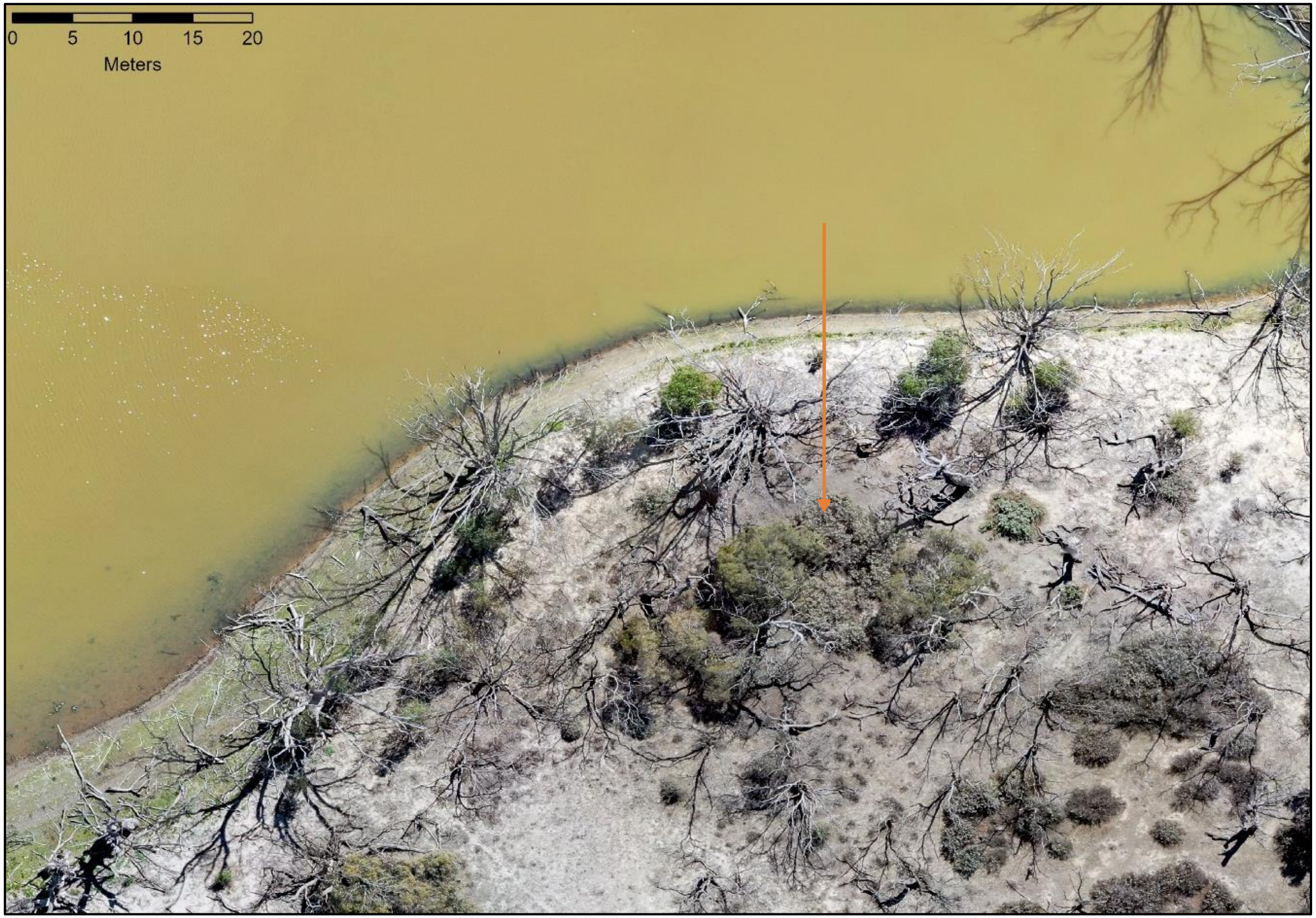
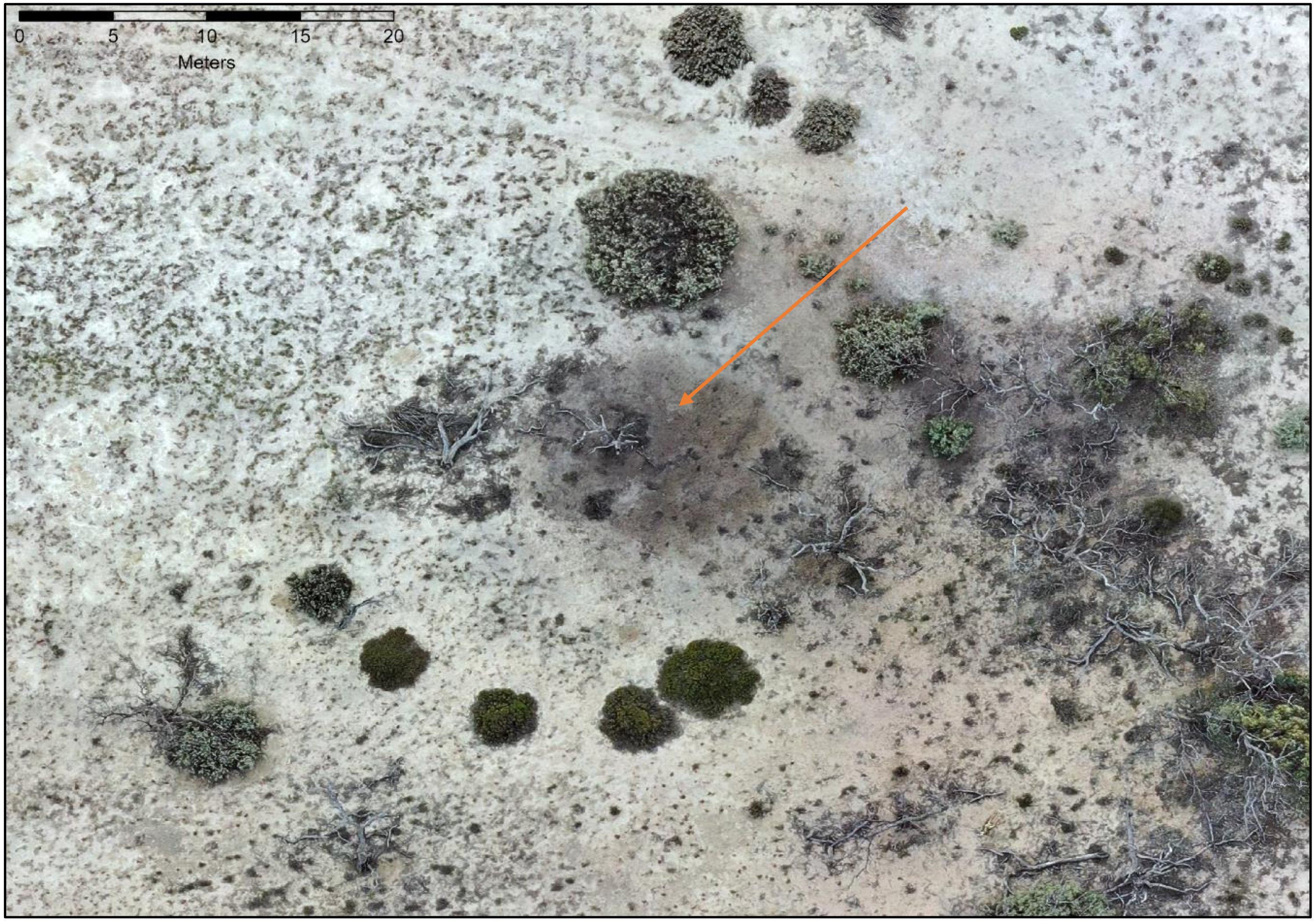


Figure 10A.4 Mound HIS_2_23. Double Thookle Billabong at the top (north) of the photograph.



10A.5: Mound RRWWS3. Ra Ral Wide Water Lagoon is located to the right of the mound toward the southeast (out of picture).