Setting the Scene: Preliminary Archaeological Investigations into the Submerged Continental Shelf of South Australia – Geomorphology, Context and Significance

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Declaration of Candidate

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

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Abstract

Over the last 50,000 years, changes in sea levels due to Quaternary glacial processes saw the Australian continent vary in the configuration of its extent and topography. During this time, this dynamic environment provided the context to the arrival and subsequent occupation of its terrestrial landscape by Indigenous peoples. Through the process of this colonisation, in relation to lowered sea levels, Indigenous peoples may have interacted with the then terrestrial landscape of the now submerged continental shelf. Numerous interdisciplinary archaeological investigations around the world have demonstrated the significance of understanding past environmental landscapes in relation to investigating past human activities; the extent to which includes the potential for material evidence relating to past human/environmental interactions to exist underwater on shelf areas. Simultaneously, a great deal of information is known about the submerged continental shelves of Australia from a multitude of disciplines. However, the combining of these two areas of research has been explored to a limited extent in the Australian context. The focus of this study is therefore centred on understanding the topographical changes of South Australia, over the last 50,000 years, in relation to the Australian Indigenous archaeological discourse. Specifically, it establishes a generalised environmental context for South Australia; determines that South Australia's terrestrial landscape extent in the past was simultaneously highly mobile and unchanging until the Mid Holocene leaving it open to human interactions; calibrates radiocarbon dates for archaeological sites in South Australia, as well as displaying these against the appropriate contemporaneous context (dispersal of sites throughout space and time); and develops a dialogue of significance surrounding the aforementioned South Australian landscape and its changes, and its continued investigation within archaeology; as a means of both adding interpretations to terrestrial investigations, and beginning the investigation of the underwater environment to gleam new information about past human activity.

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To my many doctors, thank you for helping me get through this in one piece, mostly.

To the friends I made along the way, thank you for the moral support. Forever my sounding boards.

Finally, to my family, I love you all and hope that I have made you proud.

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Chapter 1: Introduction

'Submerged continental shelves are as much parts of given prehistoric landscapes as those of adjacent mainland areas and offshore islands' (Dortch 2002:37).

1.1 Statement of Purpose

Within archaeology, it is widely accepted that, during the spread of atomically modern humans, the world's sea levels fluctuated between 0 to 120 metres below the current mean sea level (Bailey and Flemming 2008:2153–2154; Birdsell 1977:115; Harff et al. 2016:1–3). In conjunction with this, archaeologists have recovered countless artefactual remains from locations on the submerged continental shelf which correspond with these lowered sea levels. Archaeologists have therefore come to recognise that humans would have traversed, occupied, and interacted with these areas (Flatman and Evans 2013:2). However, the investigation of human movements and interactions within these areas has been largely forgone in Australia. Yet, its study offers opportunities to investigate the nature of past human/environmental relationships. Specifically, those questions concerning the use of inland and coastal areas, the nature of Late Pleistocene Indigenous settlement patterns within coastal areas, and responses to glacial related environmental changes (Cane 2001; Veth et al. 2016a, Williams et al. 2013). The problem in addressing these questions is comparatively linked to the nature of the archaeological discourse in Australia; where topics of context and preservation play key roles in the investigation and interpretation of cultural material. The issue with these topics extends to the extent of knowledge around environmental and cultural contexts, and the nature of preservation. This study is concerned with the former, the limitations of interpretation that arise from the minimal knowledge acquired for environmental and cultural contexts. Understanding the latter can only be achieved through a greater understanding of context, which informs the nature of deposition, the environment, cultural material types, and the nature of site disturbance (Frankel 1993:25–29; Smith and Sharp 1993; Veth et al. 2016b:82).

The extent to which archaeological investigations in Australia focus on past environmental contexts is marred, in part, from a lack of investigation into the nature of the entire Sahul landscape; Sahul as the continental landform of Australia created during times of lowered sea levels (Ballard 1993; O'Connell and Allen 2004:835). For the most part, investigations of archaeological sites do refer to this landform, however few have considered it as a main investigatory area as it relates to context of Indigenous migration, environmental change, and human/landscape interactions (Bird et al. 2016; Birdsell 1977:148; Cane 2001; Nicholson and Cane 1994; Smith and Sharp 1993:49–54). A major component of this landform is the submerged continental shelf. Overall, archaeological investigations into the submerged continental shelf have gained momentum in Australian archaeology, though investigations are few and vary in their application and purpose (Dortch and Godfrey 1990; Dortch 1991; Flemming 1983; Nutley 2005, 2014, 2016; Ward et al. 2013; Ward et al. 2015; Ward et al. 2016). Investigations primarily focus on the potential of Indigenous archaeological sites to exist on shelf areas in relation to studies of present shelf environments, and the methodology for which to conduct investigation of the areas. It is only recently that Veth et al. (2016a:8–9) have alluded to the use of submerged continental shelf studies to aid in understanding the Indigenous past. Therefore, this study will conduct a preliminary investigation into the topographical history of South Australia, focusing on the submerged continental shelf, over the last 50,000 years, in order to establish a generalised environmental context, and discuss the archaeological significance of incorporating this context within Indigenous archaeology. South Australia was chosen as the study area because no archaeological investigations of this nature have occurred thus far, and the area holds many unique environments within its borders.

1.2 Research Question, Aims, and Objectives

The questions asked by this study are:

- What were the topographical changes that occurred within South Australia over the last 50,000 years? and
- How does investigating these topographical changes contribute to the discourse of Indigenous archaeology in South Australia?

The date of 50,000 years is used as an earliest arrival date for humans in South Australia (Lourandos 1997:296). These questions aim to:

- Contextualise South Australian Late Pleistocene and Early Holocene topographic changes in relation to the chronology of human presence and activity in the area, and
- Demonstrate the archaeological significance of understanding topographic changes of the submerged continental shelf from a South Australian perspective.

In order to address these questions and aims, the objectives of this study are to:

- Identify the geomorphological processes affecting topography of South Australia over the last 50,000 years, focusing on the submerged continental shelf;
- Define sea-level fluctuation history for South Australia;

- Describe the physical nature of South Australia's topography throughout the last 50,000 years;
- Conduct significance assessment of this topography and its changes in relation to Indigenous archaeological discourse in South Australia; and
- Present recommendations for future archaeological investigations in relation to this landscape.

1.3 Study Area

The study area of this investigation is comprised of the state of South Australia and the adjacent submerged continental shelf (Figure 1.1). The South Australian submerged continental shelf is an area of approximately 200,000 km^2, a comparative size to those shelf areas in north of Australia. The current terrestrial environment is comprised of varying coastal marine environments (i.e. coves, inlets and gulfs), riverine environments, arid interior environments, and temperate climatic regimes along the Peninsulas and in the southeast (Belperio 1995a:218–219). The submerged continental shelf is comprised of three main elements: the inner, middle, and outer shelf (James et al. 2001:553).

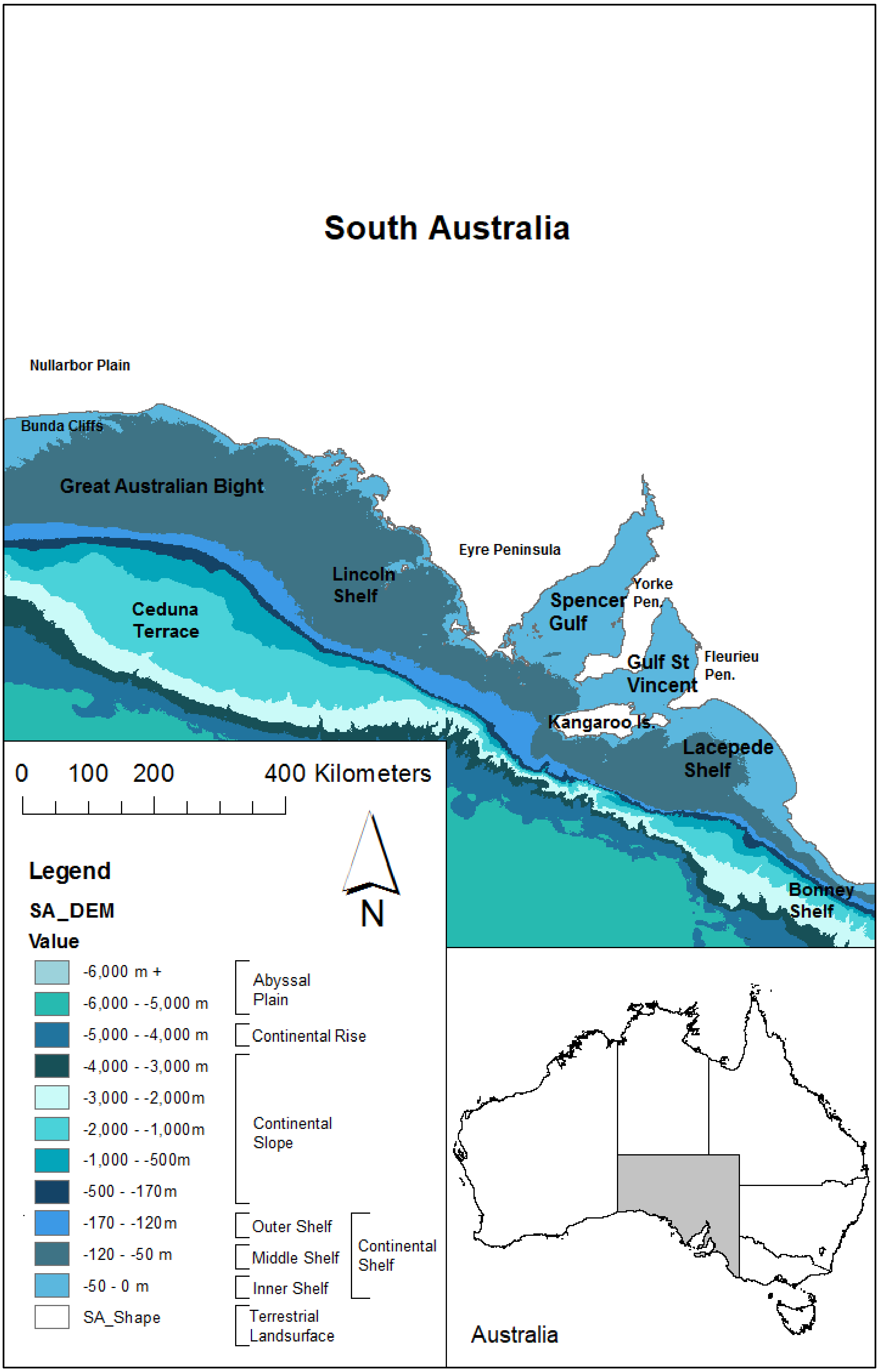
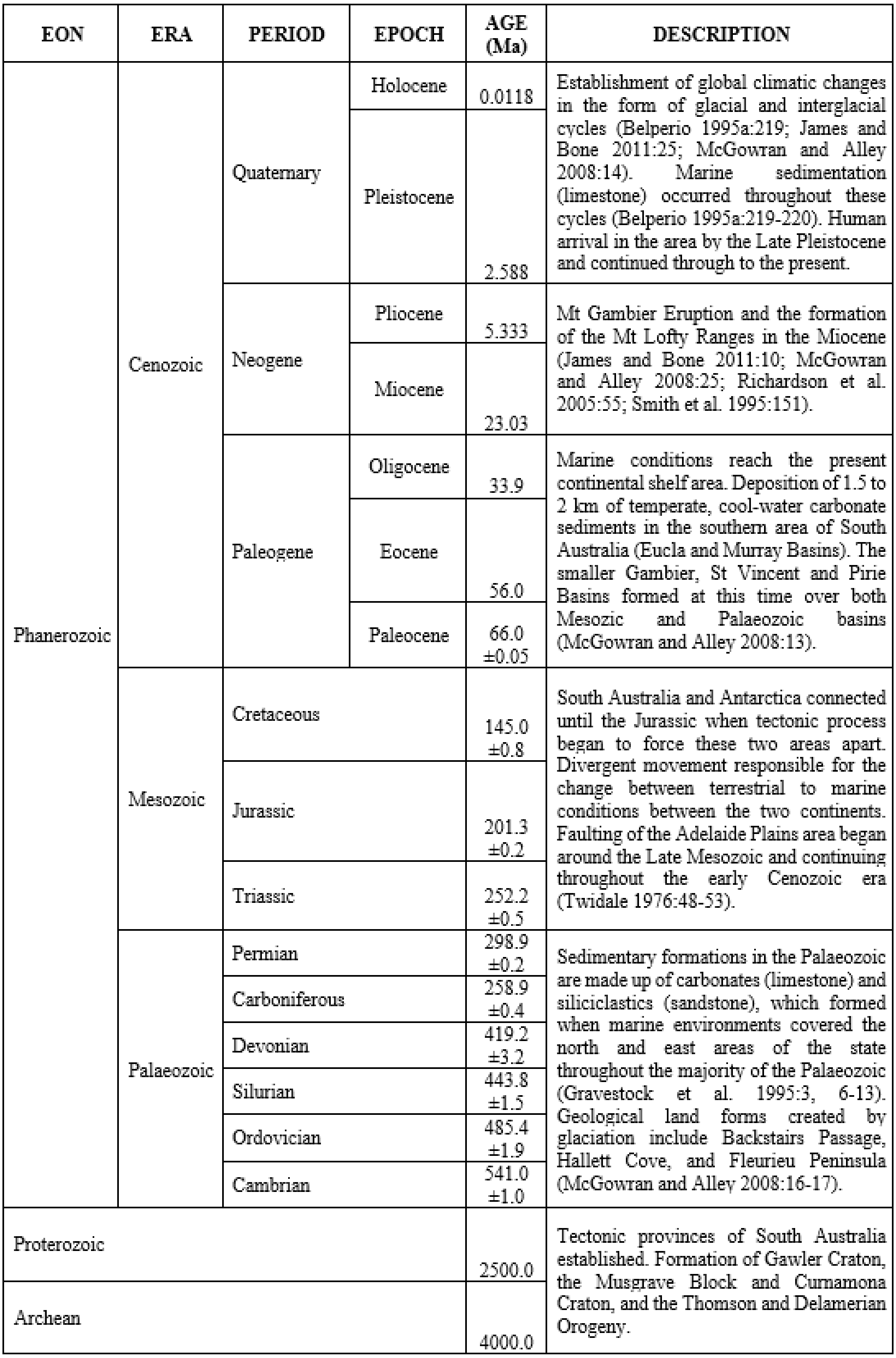


Figure 1.1: South Australia's continental extent (exposed and submerged).

1.3.1 Tectonic Framework and Geological Background

South Australia's lithosphere is well documented by publications such as those created by the Royal Society of South Australia, the Geological Survey of South Australia (Drexel and Preiss 1995), Geoscience Australia, Bourman et al. (2016) and James and Bone (2011). This section highlights the major geological developments of South Australia which provide the foundations on which geomorphological processes occurred in the Quaternary. South Australia's continental composition is the result of millions of years of geological processes operating on the earth's surface (Figure 1.2). The main tectonic provinces of the region, established throughout the Archean to the Early Palaeozoic, amass into a relatively stable tectonic area covering much of the South Australian region (Figure 1.3a) (Murray-Wallace 2014:273; Prothero and Schwab 2004:438).

It is within the Phanerozoic, however, that the majority of South Australia's formations occur. The major feature of this eon is the processes impacting the supercontinent Gondwana occurring between the Early Cambrian through to the Mid Cretaceous (Gostin and Hill 2014:25; Gravestock 1995:3; Krieg 1995:93; Murray-Wallace 2014:273). Sedimentary formations in the Palaeozoic were created through tectonism, eustasy and sediment supply, the majority of which occurred in the north of the state (Figure 1.3b) (Gravestock et al. 1995:3). Widespread glaciation occurred towards the end of the Palaeozoic and was characterised by glacigenic sedimentation (Alley 1995:63; Gostin and Hill 2014:25; McGowran and Alley 2008:15). The Mesozoic era saw South Australia landlocked in the Triassic period, with a small amount of sedimentation occuring in the north of the state (Krieg 1995:93; McGowran and Alley 2008:18). The rest of the state was characterised by subaerial weathering, including what is now the continental shelf (Krieg 1995:93).



EON	ERA	PERIOD	EPOCH	AGE (Ma)	DESCRIPTION
Phanerozoic	Cenozoic	Quaternary	Holocene	0.0118	Establishment of global climatic changes in the form of glacial and interglacial cycles (Belperio 1995a:219; James and Bone 2011:25; McGowran and Alley 2008:14). Marine sedimentation (limestone) occurred throughout these cycles (Belperio 1995a:219-220). Human arrival in the area by the Late Pleistocene and continued through to the present.
			Pleistocene	2.588	
		Neogene	Pliocene	5.333	Mt Gambier Eruption and the formation of the Mt Lofty Ranges in the Miocene (James and Bone 2011:10; McGowran and Alley 2008:25; Richardson et al. 2005:55; Smith et al. 1995:151).
			Miocene	23.03	
		Paleogene	Oligocene	33.9	Marine conditions reach the present continental shelf area. Deposition of 1.5 to 2 km of temperate, cool-water carbonate sediments in the southern area of South Australia (Eucla and Murray Basins). The smaller Gambier, St Vincent and Pirie Basins formed at this time over both Mesozic and Palaeozoic basins (McGowran and Alley 2008:13).
			Eocene	56.0	
			Paleocene	66.0 ±0.05	
	Mesozoic	Cretaceous		145.0 ±0.8	South Australia and Antarctica connected until the Jurassic when tectonic process began to force these two areas apart. Divergent movement responsible for the change between terrestrial to marine conditions between the two continents. Faulting of the Adelaide Plains area began around the Late Mesozoic and continuing throughout the early Cenozoic era (Twidale 1976:48-53).
		Jurassic		201.3 ±0.2	
		Triassic		252.2 ±0.5	
	Palaeozoic	Permian		298.9 ±0.2	Sedimentary formations in the Palaeozoic are made up of carbonates (limestone) and siliciclastics (sandstone), which formed when marine environments covered the north and east areas of the state throughout the majority of the Palaeozoic (Gravestock et al. 1995:3, 6-13). Geological land forms created by glaciation include Backstairs Passage, Hallett Cove, and Fleurieu Peninsula (McGowran and Alley 2008:16-17).
		Carboniferous		258.9 ±0.4	
		Devonian		419.2 ±3.2	
		Silurian		443.8 ±1.5	
		Ordovician		485.4 ±1.9	
		Cambrian		541.0 ±1.0	
Proterozoic				2500.0	Tectonic provinces of South Australia established. Formation of Gawler Craton, the Musgrave Block and Curnamona Craton, and the Thomson and Delamerian Orogeny.
Archean				4000.0	

Figure 1.2: Chronostratigraphic table of geological history for South Australia. Dates from Gradstein and Ogg (2012:32).

Throughout the Jurassic and Cretaceous, however, a new geotectonic regime began, identified by the rifting between Antarctica and Australia (part of Gondwana), along the Otway, Duntroon, and Bight Basins (Figure 1.3c) (Gostin and Hill 2014:25; Krieg 1995:92–93); these basins are characterised by sandstone and siltstone (Hill 1995:135). This rifting created a divergent margin in which the Antarctic and Australian continental plates progressively moved away from each other (Gostin and Hill 2014:25; Krieg 1995:92–93; Murray-Wallace 2014:273; Richardson et al. 2005:54).

This movement caused the transition from terrestrial to marine conditions for South Australia; though marine conditions did not reach the present continental shelf area until the beginning of the Cenozoic era (Benbow et al. 1995a:208–210; Benbow et al. 1995b:151; Krieg 1995:93). These marine conditions, unconformably depositied 1.5 to 2 km of temperate, cool-water carbonate sediments onto the underlying Mesozoic basins, forming the current passive continental margin; comprised of the Eucla and Murray Basins (Figure 1.3d) (Benbow et al. 1995b:151; James and Bone 2011:9; Murray-Wallace 2014:279–280). Through times of marine conditions, terrigenous sediment supply was limited (Richardson et al. 2005:55). The Cenozoic also saw the formation of the gulf regions (Pirie Basin and St Vincent Basin), with the Spencer Gulf depressed over underlying fault structures (Gostin and Hill 2014:25; Lindsay and Alley 1995:164; Richardson et al. 2005:75). Marine deposits from both basins underlying the gulf areas exhibit similarities in structure, though sedimentation in these areas was diachronous (Alley and Lindsay 1995:175; Murray-Wallace 2014:280).

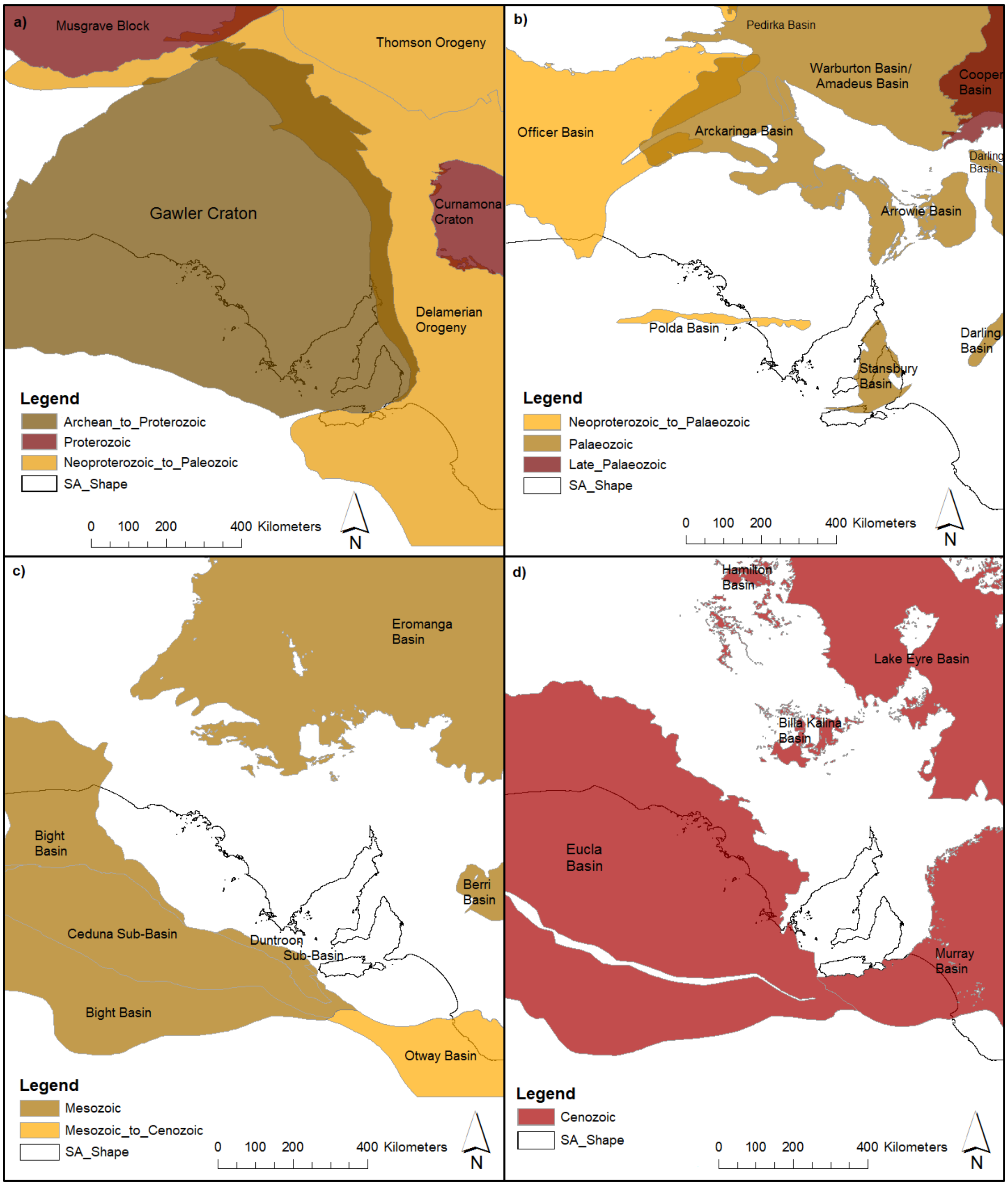


Figure 1.3: Tectonic provinces and sedimentary basins of South Australia (after Stewart et al. 2013). Insert a) illustrates the tectonic provinces whilst Insert b), c) and d) illustrate the sedimentary basins corresponding to the Palaeozoic, Mesozoic, and Early to Middle Cenozoic respectively.

1.4 Significance

The significance of this study lies in its ability to contribute to the new understandings about context and its inclusion in the study of the human past in South Australia. The study contributes to the discourse of both submerged landscape studies and Indigenous archaeology in South Australia. Applicable to both discourses, it is the first archaeological investigation into the submerged continental shelf of South Australia. It contributes preliminary archaeological analyses of the terrestrial topographic changes of the submerged continental shelf to help understand the human past in South Australia. These changes have not been considered previously in archaeological investigations beyond the point of general reference. It also furthers the incorporation of submerged landscape methodologies within Indigenous archaeological practices. This study complements discussions concerning the nature of Late Pleistocene and Early Holocene coastal occupation and marine resource use, Indigenous responses to sea-level changes, and Indigenous population movements in South Australia. Finally, this study could be used to direct further research in both submerged landscapes and archaeological context studies in the region.

1.5 Limitations

The primary limitations of this study are the scope, accuracy, and accessibility of the data (environmental and cultural). In terms of scope, only environmental data that has been acquired for large areas is utilised for the investigation of the submerged continental shelf. As such this study is inherently generalised. This generalisation limits the degree of detail that is discussed within the study. An example of this is the knowledge surrounding the potential existence of micro environments within the Late Pleistocene. In terms of accuracy, data collected may be inconsistent when compared to one another. This is due to the nature of data collection for this study, where data is acquired from secondary sources. Measures are taken to limit this inconsistency. Gaps in data should be filled by further investigations. In terms of accessibility, cultural data usage will be limited to site descriptions available through publicly available sources.

Environmental data is also limited to accessibility, again, by the nature of data collection. This study does not collect new primary data relating to either the submerged continental shelf of South Australia or Indigenous archaeological sites in South Australia.

1.6 Notes on Terminology

Several terms are fundamental to this study that require explanation. Within social science disciplines, the term 'landscape' is used to denote a space that has cultural signifiers (both tangible and intangible) (Daniels and Cosgrove 1988:1; Ford 2011:1; Seymour 2000:193). Moreover, 'landscape' can be used further to imply those with specific cultural attributes, for example a maritime cultural landscape (Ford 2011:4–5; Westerdahl 1992). However, 'landscape' is also used to specify a physical land surface and its environmental attributes (Daniels and Cosgrove 1988:1; Seymour 2000:193). For the purpose of analysis, this study utilises the later definition of 'landscape'. This is due to the limited knowledge on Indigenous cultural interactions and connections with the submerged continental shelf (as a cultural landscape); though this limitation is not a deterrent of investigation (see Nunn and Reid 2016:15–18, 33). Within this study, the term 'scale' denotes the detail presented within an area (e.g. large scale depicting large details) (Flemming et al. 2017a:7). However, the reverse of this occurs when area is referred to explicitly without mention of the word scale; that is a large area or space is greater in size than a small area or space.

For the purposes of this study, the term 'Indigenous' is utilised to identify the first anatomically modern humans to arrive in Australia (AIATSIS 2018). The study refers to specific traditional Aboriginal Australian groups and their descendants where appropriate. While there is no doubt that living Aboriginal peoples have traditions regarding submerged areas as a part of their cultural landscapes (Nunn and Reid 2016), any identification of specific Aboriginal group's connections with the submerged continental shelf is beyond the scope of this study.

In the reporting of dates, years representing age or a period in time prior to this study are written in long form (e.g. 50,000 years or 9,000 years ago). The convention of 'BP' (acronym of Before Present) is employed to demonstrate when dates have been radiocarbon dated, based on the reporting methods of Flemming et al. (2017a:7–8), Lambeck et al. (2014:15297), and Ward et al. (2013). Error margins are expressed where appropriate (e.g. 12,345 ± 678). For dates which have been calibrated, the convention of 'cal. BP' is employed (Flemming et al. 2017a:8). It is acknowledged here that calibration is preferred when discussing both archaeological sites and past environments. Therefore, calibration of radiocarbon dates is conducted where applicable (See section 3.1.2).

1.7 Chapter Outline

This chapter has introduced the research conducted by this study and the reasoning behind its investigation. This chapter has also: described the research questions, aims, and objectives; briefly defined the study area; provided comments on the significance and the limitations of the research; and clarified the terminology used for this study.

Chapter Two reviews environmental archaeological theory in order to undertake the analysis of topography in relation to the human past. It also further elaborates on the archaeological element in which this study concerns; context. Moreover, it provides a review of the archaeological context of South Australia, specifically concerning those dated archaeological sites which can be tied to topographic changes.

Chapter Three outlines the methods of data collection and analysis used to determine the topographical changes in South Australia. Chapter Four presents the results obtained by the investigatory methods detailed in Chapter Three. The chapter details the results of the geomorphic history of South Australia, and presents a series of models detailing the resultant topographic changes.

Chapter Five discusses the results of Chapter Four, outlining a narrative of changes, and examines these changes in relation to the Indigenous archaeological discourse of South Australia. Specifically, it demonstrates the archaeological significance of environmental context of South Australia, and presents avenues of further research into the submerged continental shelf of South Australia. Reference is also made to wider Australian contribution. Chapter Six re-examines the questions, aims, and significance of this study, and presents concluding remarks on the discourse of submerged landscape studies in Australia.

Chapter 2: Literature Review

This chapter examines the theoretical frameworks which guide investigations of human/environmental relations. Specifically, this review discusses the theory employed within environmental archaeology and the element of context. Environmental archaeology is recognised here as a sub-discipline through which submerged landscapes are investigated. Moreover, this chapter will provide an overview of the archaeological context of South Australia. This overview is conducted to link archaeological sites to topographical context, which is used to tie topographical contexts to discussions within the current archaeological discourse.

2.1 Environmental Archaeology

Environmental archaeology is a sub-discipline within archaeology which is intrinsically concerned with understanding the relationship between humans and the environment; so too are submerged landscapes studies (Flemming et al. 2017a:3; Reitz and Shackley 2012:1,469–473). Initially, site interpretations detailing past human activities were void of landscape context, however recently there has been a movement towards understanding physical site settings as fundamental to site interpretations (Renfrew and Bahn 2012:223). Of the many elements within environmental archaeology, reconstruction of past environments is essential (Dincauze 2000:20; Renfrew and Bahn 2012:223). If archaeologists are to understand past human behaviour, it is integral to understand these past environments; the physical and biological contexts within which these behaviours occurred (Dincauze 2000:23; Reitz and Shackley 2012:2). The study of environmental archaeology therefore 'contributes *context* to the study of past human behaviour' (Dincauze 2000:77–78). However, as emphasised by Dincauze (2000:77–78):

> Knowledge of human environments will not explicate the ultimate causes of human evolution or history, but without detailed knowledge of past environments we cannot aspire to any deep understanding of human behaviour.

With context the focus of this study, this section reviews the environmental theory associated with environmental archaeological studies. The main theories within environmental archaeology are determinism, possibilism, and cultural ecology, which all focus on the relationship between humans and the environment (Figure 2.1) (Reitz and Shackley 2012:4). The relationships are expressed in each theory with environment as defining, non-defining, and relational to culture, respectively (Reitz and Shackley 2012:7).

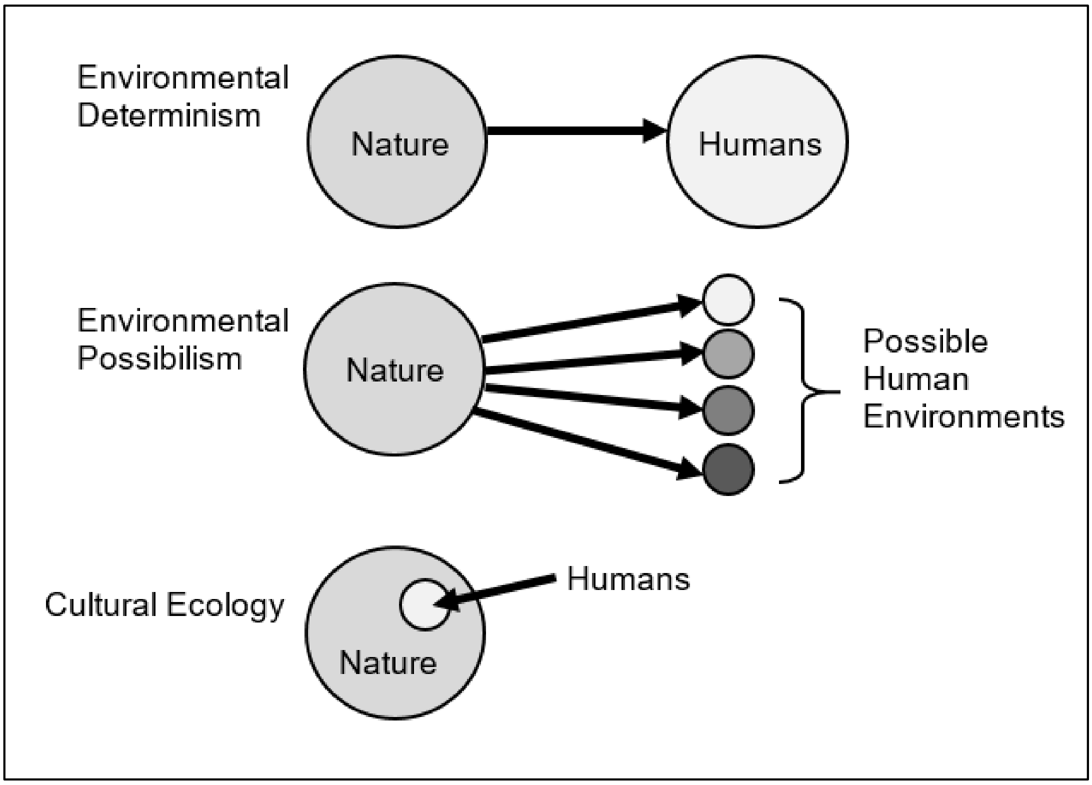


Figure 2.1: Human-environment relations (after Jeans 1974:37).

Environmental determinism follows the belief that the development of behavioural attributes of a cultural group are determined by the physical location and environmental conditions in which the group is situated (Arnold 1996:5; Reitz and Shackley 2012:7). The term was coined by Ratzel in 1882 in his first volume of *Anthropogeographie* (Semple 1911:v). The work was elaborated on by Semple (1911:1), which saw humans as a product of the earth and were therefore intrinsically governed by their environment. Likewise, all historic developments were shaped by their geographical setting (Semple 1911:10). Huntington (1960:13–16) furthered these arguments, advocating that the material needs of people and sociocultural characteristics were determined by the nature of their geographic surroundings. The geographical setting and its environment were thought to affect humans physically (physical adaptation), and psychically (belief systems, thought and speech), whilst influencing development (determinant of population size), and directing movement and distribution across space (Semple 1911:33,40,43). The argument was based on the supposition that all studies concerning the human past, aimed at explaining causes of events, failed due to the inadequacies of investigations into the geographic factor (Semple 1911:2). The geographic factor, at this time, was seen as a stable force throughout history, and thus provided a physical basis for all events (Arnold 1996:4; Semple 1911:2). These arguments say more about the nature of the thought processes of academics at the beginning of the 20th century, rather than those based on scientific evidence. The argument, however, continues to take residence in current scholarly work, most notably in spatial analysis. The need to identify the geographic factor within environmental determinism manifests itself within current human/environmental studies, where there is a need to define the environment in relation to human behaviour (Fisher 1999:9; Llobera 1996:612–613).

Though environmental determinism prevails in the foundations of environmental studies, scholars abandoned the theory as an explanation of cultural change in the early 20th century. Following this abandonment, the theory of environmental possibilism gained popularity among environmental scholars, arising from the shifting epistemology of Ratzel, evident in his second volume of *Anthropogeographie* in 1891 (Meyer and Guss 2017:30; Norton 2000:53; Spate 1968:93). Through Ratzel, followers of his work, such as Vidal de La Blache and Lucien Febvre developed the theory further (Meyer and Guss 2017:30; Norton 2000:53; Spate 1968:93). Coined by Febvre, environmental possibilism followed the belief that the environment sets limits to the variety of adaptations and behavioural attributes of a cultural group, to which alternative developments can occur in the same environment type (Fisher 1999:9; Jeans 1974:38; Trigger 2006:319). Environmental possibilism, although argued as separate from determinism, still retained the deterministic view that developments were dependant on the influence of environmental factors (Berdoulay 2009:315; Febvre 1966:33–34; Huntington 1960:11–18; Jeans 1974:38; Meyer and Guss 2017:30). This view was also reciprocated in the theory of probabilism. Probabilism, viewed cultural adaptations and behaviours as subjective to the limitations presented by an environment, however, those adaptations and behaviours were more likely to change within one limitation over all others; the most probable scenario (Fisher 1999:9). The result was then argued to govern accepted cause and effect as a way to discern scientific explanations (Spate 1968:96). Further to this, Spate (1968:96), specified that probabilism, more so than possibilism, was structured so that it provided a predictive element to explaining culture change, beyond that which non-environmentalists would allow. As such, with an element of predictability, both possibilism and probabilism are established within the foundations of spatial analysis where scholars try and predict actions of human behaviour and cultural change, depending on the variables of the environment.

In the mid to late 20th century, further redirection in theory application occurred, in which ecological theories were applied to understand human/environment relationships (Reitz and Shackley 2012:7). Developed by Steward, cultural ecology follows the belief that cultures are adaptable to their surrounding environment, and the material evidence of those cultures represent those adaptations (Ellen 1982:53; Jeans 1974:40; Johnson 2010:173; Steward 1955:30,36). Furthermore, it seeks to 'explain the origin of particular cultural features and patterns which characterize [sic] different areas rather than to derive general principles applicable to any cultural-environmental situation' (Steward 1955:36). Environments are seen to play an active role in cultural circumstance, whether affecting or being affected by human activity, but are in no way deterministic (Ellen 1982:53). The most notable aspect of this theory to the study of cultural changes manifests in the application of systems-based analysis, where humans and environments are seen to as interacting systems (Jeans 1974:40; Reitz and Shackley 2012:8). The ideas of 'environment' and 'culture' are subsequently transformed from independent wholes to be studied separately into integrated concepts (Ellen 1982:53). Systems analysis was therefore argued to present a greater awareness of the general significance of understanding human/environment relations (Ellen 1982:69). Eventually, this theoretical approach led to the investigation of context as an element required within the study of human/environmental relationships and cultural change.

2.2 The Element of Context

Whether at an intra- or extra-site level, context is an investigatory element highly regarded within the study of archaeology; particularly in terms of supporting interpretations and analysis of cultural material, in order to understand trends in the archaeological record (Butzer 1982:4; Schiffer 1972). As an investigatory approach, as advocated by Butzer (1982:4), context 'implies a four-dimensional spatial-temporal matrix that comprises both a cultural environment and a non-cultural environment and that can be applied to a single artifact [sic] or to a constellation of sites'. However, the definition of context is often based upon its use by a person and therefore has various meanings. These meanings stem from three main terms; systemic, archaeological and circumstantial (Butzer 1982:4,6; Schiffer 1972:157–158). Systemic context concerns the cultural state through which material came into being and its subsequent use, whereas archaeological context concerns the results of such material use and the interpretation of its eventual deposition (culturally) (Schiffer 1972:157–158). Circumstantial context, however, concerns the understanding of the physical settings in which human activity occurred and in which material was deposited (Butzer 1982:4,6; Flemming et al. 2017b:74). By defining context, an understanding of cultural and non-cultural variability in the spatio-temporal realm can be developed. Fundamentally, context is the basis for which interpreted relationships have meaning.

Developed since the late 20th century, the investigation of context has been increasingly concerned with understanding the environment of the past (Butzer 1982:4; Flemming et al. 2017b:74). Previously treated as a constant, descriptive variable present throughout human history, environment, as argued by Butzer (1982:4), is a dynamic factor, comprising one component within a complex system. The environment can be one in the same (descriptive or dynamic), however, its meaning and use in any archaeological investigation must be explicitly stated. Moreover, the environment as circumstantial context is multifaceted, and concerns the concepts of space, scale, complexity, interaction and stability (Butzer 1978:192–193; Butzer 1982:7). All concepts require a level of investigation to warrant comprehensive knowledge surrounding circumstantial context. The concept of space is the most basic component. It identifies the area in which all material exists and interacts. Features identified within a space, such as topography or human groups, are treated as phenomena which exhibit spatial patterning and thus can be analysed spatially (Butzer 1978:192). The concepts of scale, complexity, interaction and stability expand on space to look at the relationships of features. Scale focuses on the size of objects and the space itself, through which various features and processes can be spatially and temporally analysed (Butzer 1978:192). Complexity furthers these analyses by investigating the varying compositions of environments and societies at varying scales (Butzer 1978:192–193). Interaction identifies the processes though which societies and environments interact within one another, internally and externally, and at varying scales and proximities (Butzer 1978:193). Lastly, stability concerns the forces that impact the development of cultures and environments, and postulates that readjustment from these forces tends towards a state of equilibrium (Butzer 1978:193). The study of these concepts is often difficult and requires an analytical approach which operates flexibly at various spatio-temporal scales (Butzer 1978:193).

The ultimate goal of circumstantial context is to establish an environmental history of a site or a location. The issue with this is that a locational specific context is established in order to solve one problem, and therefore is not applicable to addressing other problems (Fisher 1999:9). Therefore, if a general context is established for a larger area (non-specific), then more than one problem/objective can start to be addressed.

Another issue associated with circumstantial context concerns the way in which context is developed. As stated by Kvamme (2006:19), 'in nearly all cases, it has been modern environmental conditions instead of past circumstances that have been investigated'. These modern conditions exclude those geographical spaces that were once present and are now either absent or hidden. This exclusion extends into systemic and archaeological contexts, where the identification and interpretation of material deposits is often placed within the modern circumstantial context. The systemic and archaeological contexts are therefore limited in their representation of the past. As Kvamme (2006:19) highlights 'it was then-contemporaneous conditions that were relevant to locational decisions and choices made by past peoples' (Kvamme 2006:19).

2.3 South Australian Archaeological Context

Indigenous archaeology in South Australia has been conducted extensively since the 1960s, with investigations resulting from both academic and heritage sectors (see Jones 1984). Focuses of these investigations has been predominately on stone tool production, rock art (paintings and engravings), cave and rock shelter use, and fish traps (Draper 2015:232–236; Hughes et al. 2017:75–76; Jones 1984:4–9; Lampert and Hughes 1988; Pretty 1977a:40; Roberts et al. 2016). To a similar extent, investigations have looked into shell middens, scarred trees, earth mounds, and human remains (burial mounds) (Bird and Frankel 1991; Egloff et al. 1991; Jones 1984:9; Pretty 1977:40; St George et al. 2013:141; Westell and Wood 2014). Of the sites investigated, evidence of human activity predominately derives from stone artefact remains contained in either open or closed sites (Mulvaney and Kamminga 1999:207). However, this says more about the nature of preservation in Australia rather than the nature of occupation (Bird and Frankel 1991:9).

The archaeological investigations of the Indigenous past in South Australia have attributed numerous finds to the Late Pleistocene and Early Holocene (the period of focus of this study). These finds have included some of the oldest dates recorded for arid interior occupation, boomerangs, and mortuary practices attributed to the Late Pleistocene, and continued studies into distribution of rock art styles and technological developments across Southern Australia (Hamm et al. 2016:280; Hughes and Hiscock 2005; Littleton et al. 2017:98-99; Luebbers 1975:39; Pretty 1977). In order to provide a concise overview of the archaeological context in South Australia, this study examines those archaeological sites that have been dated, using absolute dating methods, to the Late Pleistocene (126,000 to 10,000 years ago) and Early Holocene (10,000 to 6,000 years ago). As such, this overview of archaeology in South Australia is not an in-depth review on the overall nature of investigations conducted, but rather a selective overview of sites that can be accurately correlated to investigations of submerged continental shelf topographic changes (as outlined by the aim of this study). Subsequently, evidence from the Middle to Late Holocene is excluded from this study due to known stabilisation of South Australian topography after 6,000 years BP; where any relation between the submerged shelf, the terrestrial landscape, and human activity is beyond the scope of this study. Any changes in sea level during this time are minute in relation to the scale of this study. Of the Indigenous sites known within South Australia, only twenty sites have been dated (Figure 2.2). This was determined through the results produced by Williams et al. (2013). In this publication, Williams et al. (2013:4612) undertook an analysis of archaeological radiocarbon dates for the Terminal Pleistocene within Australia. They used this analysis to re-evaluate models of responses made by humans to Last Glacial Maximum (LGM) climate change. Though this paper is successful in its attempt to re-evaluate climate response models, it highlights issues with any sort of small-scale analysis within Australian archaeology.

Specifically, those issues relating to a lack of archaeological investigations within key regions and the lack of Late Pleistocene Indigenous occupation represented in the archaeological record (Williams et al. 2013:4614, 4623). For South Australia, these two factors are highly visible. The Indigenous archaeological sites of South Australia are spread sparsely across the landscape, with marine/coastal sites having minimal representation during the Late Pleistocene.

For the purposes of this overview, the distribution of these sites is divided into four clusters; northeast, west, southeast, and central. Discussions around these sites are often geared towards different evidence available at these sites. In the northeast and west, the sites are discussed as they relate to the occupation of the arid zone of Australia by Indigenous peoples. In the southeast, sites are often discussed as they relate to the occupation of the climatic stable refugia region of South Australia. Those in the central region, here limited to Kangaroo Island, are often discussed as they relate to the occupation and abandonment of the island. The inclusion of the northeast region and the sites contained within is intentional to highlight the presence and nature of inland occupation. With the potentially wide expanse of terrestrial exposure across the submerged continental shelf in the past, both coastal and inland occupation could be potentially identified on the submerged continental shelf; so too a reflection of or a disparity to artefacts found in the current archaeological record. Moreover, the majority of Late Pleistocene sites are located in these areas, such that a presence of sites dated to this period is not recorded in temperate regions of South Australia; where this presence may lay offshore if identified and compared to contextual sites of the same period.

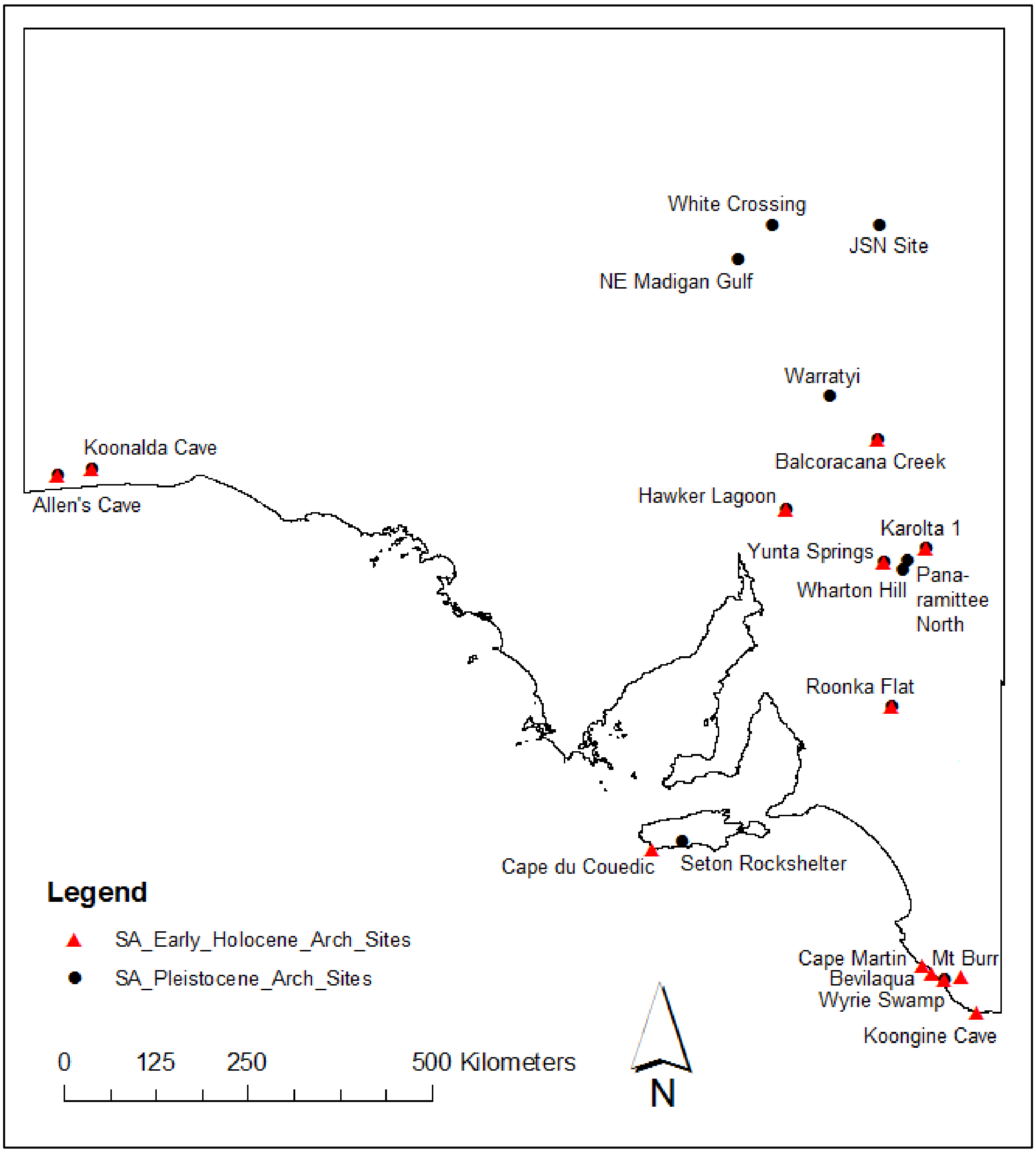


Figure 2.2: Dated South Australian Indigenous archaeological sites (after Williams et al. 2014).

2.3.1 Northeast

Discovery and interpretation of dated archaeological sites in the northeast of South Australia has occurred since the late 1980s. Investigations began with Lampert and Hughes (1987), who examined Late Pleistocene and Early Holocene occupation sites in the northern Flinders Ranges. Occupation for the region was recorded at the sites of Balcoracana Creek and Hawker Lagoon, both containing numerous assemblages of lithic artefacts, dated to ~13,000 and 14,770 ± 270 years BP respectively (Gardner et al. 1987:348; Lampert and Hughes 1988:146,148,152). Occupation was found to extend up until the end of the Early Holocene, with Balcoracana Creek up to 5,000 years BP (Lampert and Hughes 1988:148,152). Thermoluminescence dating of Balcoracana Creek also produced a date of 9900 ± 2200 years BP which also corresponds to this occupation timeline (Gardner et al. 1987:346). Gardner et al. (1987:354) caution, however, that the dates for Balcoracana Creek 'provide only an approximate chronology'. Though both these sites were dated, issues were raised over the nature of the stratigraphic record, where shifting dunes were seen to influence assemblage exposure and context (Lampert and Hughes 1988:143,147; Walshe 2005:24–25). Moreover, the purpose of these two site investigations was later questioned, where the investigations focused predominately on the establishment of regional extent of the Kangaroo Island Kartan lithic industry; the island and archaeological remains of this industry located some 500 km south of these two sites (Lampert and Hughes 1988:139,142). No further analysis of the extent of this industry on mainland Australia has taken place since these investigations (Walshe 2005).

Investigations continued within the northeast region at the JSN site. This site was the first to demonstrate the earliest occupation of the arid zone in South Australia, where in 1979, radiocarbon samples taken from hearths at the site were dated to 13,850 ± 190 years BP (Smith et al. 1991:175). Further investigations of the site in 1989 determined ages for several other hearths and lithic scatters at between 15,000 to 10,000 years BP (See Appendix 1) (Smith et al. 1991:175–177). Like Balcoracana Creek and Hawker Lagoon, investigations at JSN focused on the lithic assemblages, where these were found to originate from sources 40 km to 115 km away (Smith et al. 1991:187). With interpretations of semi-permanent residency in the Late Pleistocene and no exhibited reduction behaviour of lithics, JSN presented an atypical site compared to those relatively dated sites in the region (Smith et al. 1991:184–185, 187). Furthermore, environmental records suggest that the dates for JSN were unlikely to represent the earliest use of the site, where the authors hypothesize this date to reside closer to 17,000 to 16,000 years BP (Smith et al. 1991:190). Work by Veth et al. (1990:47) also supported the occupation of the arid zone at the end of the LGM, with the identification of sites in the Lower Cooper Creek region radiocarbon dated to a mean age of 11,800 years BP (hearths at the White Crossing site dated to 11,830 ± 320 years BP and 11,700 ± 180 years BP). The archaeological site NE Madigan Gulf, located in close proximity to White Crossing (Figure 2.2), further demonstrated earlier occupation of the arid zone, where eggshell and artefacts present within the site (surface and in situ) have been dated to 18,450 ± 165 years BP (Magee and Miller 1998; Smith 2013:145). The site and its artefacts are 'inferred to be remnants of small Aboriginal fireplaces' (Magee and Miller 1998:312). This site is presented as a demonstration of the movability of people at the high of the Last Glacial Maximum in areas of extreme aridity (Smith 2013:145).

Warratyi, a rockshelter located in the northern Flinders Ranges, presented new dates for occupation of the Northeast region, and the wider arid region of Australia. Archaeological deposits at the site were radiocarbon dated sporadically between 44,000 and 20,000 years BP (oldest date calibrated to ~48,000 years cal. BP) and consisted of lithic assemblages of various stone material, indicating a changing use of preferred material overtime (Hamm et al. 2016: Supplementary Information) (Appendix 1 and 4). Like JSN, and to a lesser extent Balcoracana Creek and Hawker Lagoon, Warratyi was discussed as its occupation related to climate (Hamm et al. 2016:282):

> Aboriginal people may have used Warratyi both as a refuge at a time when the surrounding lowlands and open plains were too arid to exploit and as a temporary campsite when environmental conditions became more stable regionally.

2.3.2 West

In the west of South Australia, the area is comprised of only two archaeological sites dated to the Late Pleistocene and Early Holocene; these being Koonalda Cave and Allen’s Cave. Koonalda Cave is an archaeological site located ~80 km east of the Western Australian/South Australian state boarders (Roberts et al. 1996:7). The site is a rockshelter located in a large karst system, where archaeological deposits of hearths and rock art were found (Roberts et al. 1996:10). The hearth features were dated to between 21,900 ± 540 and 13,700 ± 270 years BP (Appendix 1) (Roberts et al. 1996:10; Wright 1971:24). Earlier dates such as 31,000 ± 1,650 years BP are derived by Wright (1971:24), however, for replicability in dating, as exhibited by Roberts et al. (1996), the age limit of 21,900 ± 540 years BP is adhered to within this study. Unlike the sites in South Australia discussed earlier, Koonalda Cave has been a part of discussions about the nature of landscape changes in the past. Beginning with Wright (1971:14–15), discussions centre on the nature of the landscape extent and topographic features as they relate to the site location (Cane 2001:142; Martin 1973:287–288). Propositions around the nature of occupation considering the Late Pleistocene landscape are made by Wright (1971:15), highlighting the absence of evidence of Indigenous settlement of the Nullarbor Plain proper, and the possible access to resources within this landscape.

Allen’s Cave, located west of Koonalda Cave, shares similarities with Koonalda Cave. It is a rockshelter located in karst limestone, and is sporadically dated to between

39,800 ± 3100 and 8,300 ± 200 years BP (via luminescence and radiocarbon dating respectively) (Appendix 1) (Martin 1973:285; Roberts et al. 1996:8, 13). Cane (2001:143), discusses in-depth the relationship Allen's Cave had with sea level, where evidence of marine resources in the form of an abalone fragment was found at the site, dates to around 14,000 years BP. To date, Cane (2001) has been the only in-depth discussion about landscape change in the Late Pleistocene for both cave sites. A revision of Allen's Cave has been conducted by Munt et al. (2018) in relation to a technological analysis of the stone artefacts at the site. Within their investigation, Munt et al. (2018:70) recalibrate Martin's (1973:285) radiocarbon dates as a revision of Allen's Cave chronology, providing calibrated dates of 24,588 ± 2253, 14,022 ± 742, and 9865 ± 325 years cal. BP. Munt et al. (2018:71) highlight the issues with Allen's Cave chronology, focusing particularly on depth distribution of dates associated with artefactual remains. For the oldest samples dated, radiocarbon date of 24,588 ± 2253 years cal. BP and luminescence date of 39,800 ± 3100 years BP, both are recorded at a depth of 4m (Munt et al. 2018:70-71). For the purposes of their research and the uncertainty in stratigraphic continuity of the older investigations, Munt et al. (2018:71) equated Martin's (1973) date to the luminescence date. All other calibrated radiocarbon dates and luminescence dates are used interchangeably based on depth and date comparison (Munt et al. 2018:71-72). Through the analysis of stone artefacts, in conjunction with the chronology revision, Munt et al. (2018:75) determined that 'artefact quantities throughout the Allen's Cave deposit indicate infrequent visits by small numbers of foragers'.

2.3.3 Southeast

The area of southeast South Australia is comprised of eleven archaeological sites dated to the Late Pleistocene and Early Holocene. Investigations into sites in the southeast have been numerous through the last century. However, like the northeast and the rest of South Australia, dating used in these investigations have been few in regards to absolute dating. Moreover, the distribution of sites investigated by absolute dating methods has been variable. One area where absolute dating has been applied is in the north of the southeast region. The dated sites of Karolta 1, Wharton Hill, Yunta Springs, and Panaramitee North have been used to demonstrate Late Pleistocene and Early Holocene rock art sites in South Australia, specifically concerning the extent of the Panaramitee Style in Australia and southern occupation of the arid zone (Mulvaney and Kamminga 1999:372–373; Nobbs 1992). However, debate has gone on around the accuracy of attributed dates to these sites (Watchman 1992). Dates attributed to Karolta 1, Wharton Hill, Yunta Springs, and Panaramitee North can be seen in Appendix 1, though general dating corresponds to between 43,000 and 7,000 years BP; other dates are recorded for the Mid to Late Holocene (Nobbs 1992:146). These dates were thought to represent the antiquity of rock art in the region. However, these dates were later disregarded due to the inaccuracy and reproducibility of the dating methods (Flood 2004:157–158; Mulvaney and Kamminga 1999:373; Watchman 1992:55).

The site of Roonka Flat is a burial ground, found in the centre of the Southeast region, and is ‘the only systematically excavated cemetery along the Murray River’, where stratigraphy at the site was intact (Mulvaney and Kamminga 1999:305; Pretty 1977b:295). At the lowest record of human occupation, the site was dated to 18,150 ± 340 years BP, with continuous use up until the modern period; burials occur around

7,000 to 4,000 years BP to the modern period (Appendix 1) (Flood 2004:144; Littleton et al. 2017:99; Pretty 1977b:297,317). The results of the archaeological evidence at Roonka Flat are discussed in terms of the aspects of cultural change (Pretty 1977b:319). The site demonstrated 'differentiation in mortuary practices' over time, differentiation of site placement, and differentiation of cultural markers (stone and bone tools, and ornamentation) (Pretty 1977b:319–320). However, little is understood about the movement of these practices throughout the Late Pleistocene and Early Holocene landscape, largely due to the absence of archaeological evidence outside of this site. Further to these findings by Pretty (1977b) is the re-assessment of the site by Littleton et al. (2017). Littleton et al. (2017:105) found that, although there are similarities in the chronology of site use at Roonka Flat, 'there is very little indication of the way in which the site was used even in broad terms as either episodic or continuous'.

Wyrie Swamp, discovered in 1974, is an archaeological site distinct from all others in South Australia, as it is a peat site containing remains of wooden and stone artefacts dated up to 10,200 ± 150 years BP (Flood 2004:16; Luebbers 1975:39; Mulvaney and Kamminga 1999:212). The stone artefacts and their associated date supported a Gambieran technological industry (Mulvaney and Kamminga 1999:227). Other closely related sites are those of Koongine Cave, Bevilaqua, Mt Burr, and Cape Martin; all dated to the Early Holocene (Bird and Frankel 1991:6-7; Luebbers 1978:89–90) (Appendix 1). Again, these sites have not been discussed in relation to the changing Late Pleistocene and Early Holocene landscape (beyond the modern extent of Australia), but rather discussion has focused on interpretations of excavation finds (Dodson 1977; Luebbers 1978).

2.3.4 Central

The area of central South Australia is, like the west, comprised of only two archaeological sites dated to the Late Pleistocene and Early Holocene: Seton Rockshelter and Cape du Couedic. Both these sites are exclusively found on Kangaroo Island, with no other Late Pleistocene and Early Holocene dated sites found within the Eyre Peninsula, the Yorke Peninsula and the Fleurieu Peninsula. The Seton Rockshelter, excavated by Ron Lampert in the 1970s, revealed occupation of the site to be from 16,110 ± 1000 years BP (Hope et al. 1977:367; Lampert 1977:214; Mulvaney and Kamminga 1999:229). Evidence of occupation at the site is derived from the stone tool assemblages, which appear to originate from sources up to 50 km away from the site (Mulvaney and Kamminga 1999:229). Occupation of the site was sporadic between 16,000 to 11,000 years BP (Flood 2004:141; Mulvaney and Kamminga 1999:229). Abandonment of the site followed this period, with complete abandonment around 4,300 years BP (Draper 2015; Mulvaney and Kamminga 1999:229). Beyond discussion of abandonment of the island, landscape changes are relatively undervalued in terms of its archaeological potential. Most discussions have been on the nature of the lithic industry present at the site (Lampert 1977; Lampert 1981). Originally attributed to the Kartan industry, it was later found through analysis of Seton Rockshelter and Cape du Couedic that this industry is specifically associated with the Holocene (Lampert 1977:214–216; Mulvaney and Kamminga 1999:229). Re-evaluation of the Seton Rockshelter's fossil assemblage by McDowell et al. (2015:355, 357–358) produced new dates and interpretation of the site, whereby a non-human presence is recorded for the earliest site use recorded by Hope et al. (1977) and Lampert (1977) (between 17,500 to 14,000 years BP, or 21,000 to 17,000 years cal. BP), with human presence occurring intensely after this period (between 13,000 to

9,500 years BP, or 16,000 to 10,700 years cal. BP). The Cape du Couedic site, discovered in 1984, is located west of the Seton Rockshelter (Draper 1987:2). The site was dated between 7450 ± 100 to 5,500 years BP, with stone material relating to coastal resource requirements (Draper 1987:4; Mulvaney and Kamminga 1999:229). Again, the site presents discussion focused on the identification of the lithics industry (Draper 1987:6–7; Draper 2015). No discussions have yet occurred on its relationship to landscape changes linked to occupation patterns.

2.4 Conclusion

This chapter examined environmental archaeological theoretical approaches and South Australian archaeological context in order to provide a basis from which to assess the significance of studies of the submerged continental shelf to Indigenous archaeological investigations. The understanding of context is deemed vital within this study, in order to assess shelf study significance to the investigation of human movement and activity in the past. The following chapters will focus on understanding space and scale, as concepts attributed to context.

Chapter 3: Methods

This chapter presents the methods employed in the collection and analysis of data pertaining to the topography of South Australia. The methods employed consisted of a desktop survey identifying the geomorphological processes affecting South Australian topography, and landscape modelling conducted to view the resultant topographic changes. The methods enabled the establishment of circumstantial context of South Australia for archaeological purpose. The methods are described in detail to the extent that they are replicable for other investigations of this type.

3.1 Desktop Survey

The desktop survey was the first method implemented in this study. The survey facilitated the systematic collection of data relating to the topographic changes of South Australia. The data consisted of primary and secondary sources relating to the geomorphological processes which shape topography. The identification and examination of these processes is presented in section 4.1. The survey also allowed for the collection of data used in the method of landscape modelling (Butzer 1982:35). The subsequent synthesisation of the geomorphology data is used to inform examination of landscape models (Benjamin 2010:259; Flemming 2017), and the assessment of significance. The desktop survey created a means by which to present generalised information concerning South Australia’s environmental context. This builds upon the notion that any palaeoenvironmental reconstructions are only capable of broad generalisations about the past; considering the spatio-temporal scale of this investigation (Kvamme 2006:19). Both the desktop survey and the landscape modelling enabled this study to concentrate on the exploration of the concepts of space and scale presented in section 2.2.

To identify the primary and secondary sources, multiple search engines and databases were utilised. These included the search engines Findit@Flinders and Google Scholar, and the databases Trove, Geoscience Australia Data and Publications Search, DataReSource, Geoscience Australia Marine Sediments (MARS), Wiley Online, Taylor and Francis Online, SpringerLink and ScienceDirect. Primary and secondary sources of data were limited to those produced for academic, government, and industry purposes. The main approaches of this survey are: 1) the search for and collection of data for the study area; and 2) the synthesisation and analysis of the data collected (section 4.1 and section 5.1). A primary focus was placed on the collection of data pertaining to the submerged continental shelf. The secondary sources were acquired using the key search terms such as:

- South Australia
- Bathymetry
- Submerged
- Continental
- Shelf
- Geology
- Geomorphology
- Oceanography
- Hydrology
- Holocene
- Pleistocene
- Sea-Level Rise
- Sea-Level Curve
- Sea-level Change
- Last Glacial Maximum
- Landscape

All secondary sources were compiled into the database software Microsoft Access. This ensured the consistent management of data collected. The database was structured to store information set out in Appendix 2. Evaluation of these sources was guided by the practice of environmental archaeology, focusing on the process of integrating multidisciplinary research (Dincauze 2000:24). Evaluation was conducted by analysing the complementarity of the sources, the consistency of the data presented in multiple publications, and the congruency of data scale (Dincauze 2000:24). All digital data collected for the construct of landscape models were compiled into a geodatabase, managed in ArcCatalog.

3.1.1 Sea Level

A major component of topographic change, throughout the last 50,000 years, has been sea-level fluctuations. To address the objective to define the sea-level fluctuation history for South Australia, the desktop survey also comprised the collection of sea-level data relating to the region. This data was used to create a sea-level curve to aid landscape model constructions. This data is employed as an approximation of depth to age ratio of sea levels in the past (Benjamin 2010:259–260). The sea-level data acquired through the survey are comprised from three separate publications: Belperio et al. (2002), Lambeck (2004), and Lambeck et al. (2014) (Figure 3.1) (see section 4.1.1.1 for results of sea-level curve and appropriateness to study area in terms of geomorphological processes). All dates were produced by radiocarbon and uranium series dating (Belperio et al. 2002:156-157; Lambeck et al. 2014:15297). All dates where calibrated by their respective authors or by Lambeck et al. (2014) via the atmospheric curve IntCal09 (Lambeck et al. 2014:15297).

The collection of the data occurred through two methods. The first method involved gathering data from the supplementary information provided by Belperio et al. (2002: Supplementary Data), and Lambeck et al. (2014: Supporting Information Appendix). The second method involved using observational recording to ascertain the corresponding relative sea-level depths from Lambeck (2004) for periods of 1,000 years between 35,000 to 50,000 years cal. BP. All individual data points were then entered into Microsoft Excel, with each publication having a separate sheet corresponding with their publication; a single sheet was also created to display all data. The only post processing of data that took place was the refinement of sea-level data from Belperio et al. (2002:161) as outlined by the authors. Refinement required the rejection of all subtidal indicators, beach ridge and Chenier samples, where these indicators have a high inconsistency with data results (Belperio et al. 2002:161).

In order to establish a sea-level curve, a line of best fit through the data was determined the best proxy for South Australia as a region. To establish a line of best fit, the data of Belperio et al. (2002) and Lambeck et al. (2014) was averaged. Averages were used to establish singular data points for 500-year intervals (Appendix 3). This was done by calculating the averages of depths between a set date bracket (sum divided by count); that is ages between *N*250 and *N*749, and *N*750 and *N*249, with *N* representing a numeric value (age) between 0 and 35 (e.g. *N*=12, depth between 12,250 and 12,749 years cal. BP); with ages above 35,000 years cal. BP determined elsewhere. This applied only to the publication data produced by Belperio et al. (2002) and Lambeck et al. (2014). After averages were produced, the results were placed into a new excel sheet in order to produce a graph detailing a line of best fit. The subsequent sea-level curve was produced by displaying the results as a scatter with smooth lines graph. Colour and width of the line were adjusted accordingly. For modelling purposes, where depth data was unknown, single age data was used from the combined sea-level curve.

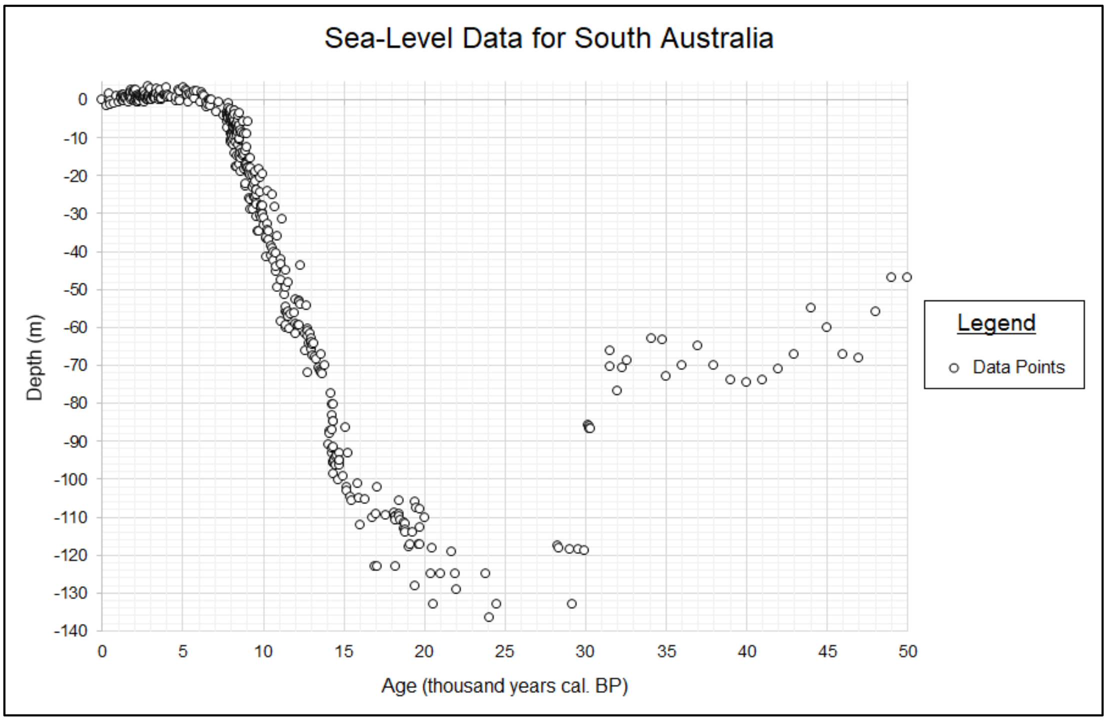


Figure 3.1: Sea-level data from Belperio et al. (2002), Lambeck (2004), and Lambeck et al. (2014).

3.1.2 Radiocarbon Calibration

In order to tie archaeological sites to their contextual landscape, calibration of site radiocarbon dates, presented in section 2.3 and Appendix 1, was undertaken. This was done to allow ‘for a more accurate association of artefacts [and sites] with palaeoenvironmental events’ (Munt et al. 2018:72); specifically, the calibrated sea level dates provided in section 3.1.1. The method of calibration involved utilising the online calibration program OxCal (version 4.3.2) (Bronk Ramsey 2009). The atmospheric calibration curve selected was the current curve for the southern hemisphere (SHCal13) (Hogg et al. 2013). The southern hemisphere atmospheric calibration curve was selected for consistency in display of pre-existing calibrated data (using the same curve) and to accurately tie radiocarbon dates with their corresponding hemisphere, where minute differences are exhibited between northern and southern hemisphere curves (Hogg et al. 2013:1889). Where pre-existing calibrations use the northern hemisphere curve, these were left untouched as the differences discussed by Hogg et al. (2013:1889) were determined to be inconsequential in regards to the scale of time and space of the area being investigated (this specifically applied to the calibration produced by Munt et al. 2018). Greater analysis of both archaeological site dating and sea-level dating is advisable for future investigations.

The resulting calibrated radiocarbon dates and corresponding time periods are present in section 4.1.3 and Appendix 4. The sites calibrated were updated to display only those sites usable for calibration and time-series analysis (William et al. 2014). Some dates were removed where upon further investigation, the dates did not correspond with a recorded cultural presence at a site (e.g. sample ANU-1221 re-evaluated by McDowell et al. 2015:358). Likewise, dates were added where review of these sites permitted the inclusion of some dates (e.g. sample NZA 25830 produced by McDowell et al. 2015:358 and samples by Murray and Roberts 1997:167). The results of the calibrations are used for the display of archaeological sites against modelled landscape changes (see Appendix 5b).

3.2 Landscape Modelling

The second method implemented was landscape modelling. The process of landscape modelling enabled the visualisation of South Australian topographic changes. Visualisation was utilised as a tool to conduct a spatial analysis of landscape context, which is used to address the third objective. Landscape is considered within the study as a geographical area which is definable and where that definition can be improved. The geographical area is then considered as a model which must be verified and validated (model testing) (Dore and Wandsnider 2006:80–81). If models are not improved, 'an assumption is made that an adequate understanding of the factors that condition [landscape changes and] human land use exist' (Dore and Wandsnider 2006:81).

The use of landscape modelling and application of geographical information systems (GIS) in this study is based on the notion of the exploration of 'possible' in archaeology (Fisher 1999:9). Therefore, only data that is appropriate to the investigation is incorporated, and is applied with 'a realistic measure of the epistemology of the investigator' (Fisher 1999:9). As a basis for the investigator's epistemology, it is recognised that maps produced in archaeological investigations are more so based on the physicality of known sites, rather than the areas of unknown, to the extent that any map 'may tell more of preservation and/or discovery and/or analysis than of cultural possibilities' (Fisher 1999:9). Likewise, maps that are used as an interpretive tool, based on limited data, should be indicative rather than definitive of the period of investigation (Fisher 1999:9).

Landscape modelling for this study consisted of producing two and three-dimensional model-based reconstructions of South Australia and its submerged continental shelf derived from bathymetric and topographic data. These models established the extent and characteristics of South Australian topography throughout the past 50,000 years. To accurately display both major and minute changes to topography over this period, models where constructed at 1,000 year intervals. This scale offered an appropriate display of physical changes across South Australia in relation to the time span under investigation. Modelling was conducted using the ESRI ArcGIS 10.4 for Desktop software systems ArcMap and ArcScene. The layer types (raster datasets and feature classes) created throughout the following processes were stored in a file geodatabase with appropriate naming systems and associated metadata.

The dataset used for this study was the ‘Australian Bathymetry and Topography Grid, June 2009’, henceforth referred to as AusDEM (DEM as the abbreviation of digital elevation model) (Geoscience Australia 2019). The dataset was provided at a resolution of 0.0025° decimal degrees, equivalent to ~250 m at the earth’s equator, and was determined to be of adequate accuracy for the purposes of this investigations (Figure 3.2) (Geoscience Australia 2019; Whiteway 2009:1). The dataset was produced by multibeam surveys, with existing data from the 2005 topography and bathymetry dataset (Whiteway 2009:1–3). The AusDEM comes projected in the coordinate system WGS 1984; this format was kept for modelling purposes. All other datasets were converted to this projection for consistency. For the projection of the archaeological site coordinates, the WGS84 coordinate system was selected. The original datum used by Williams et al. (2013) to display the archaeological sites is not stated by the authors, hence site locations are taken as a general location rather than their exact location. The bathymetry component of the AusDEM is used here as a proxy of past topography; however, this is interpreted alongside the results from the desktop survey to account for available records of physical environmental changes over time (terrestrial and marine). The basic modelling processes and desired outcomes are based primarily on the studies undertaken by d’Aploim Guedes et al. (2016), Ward et al. (2013), Westley et al. (2011), and Yanko-Hombach et al. (2017).

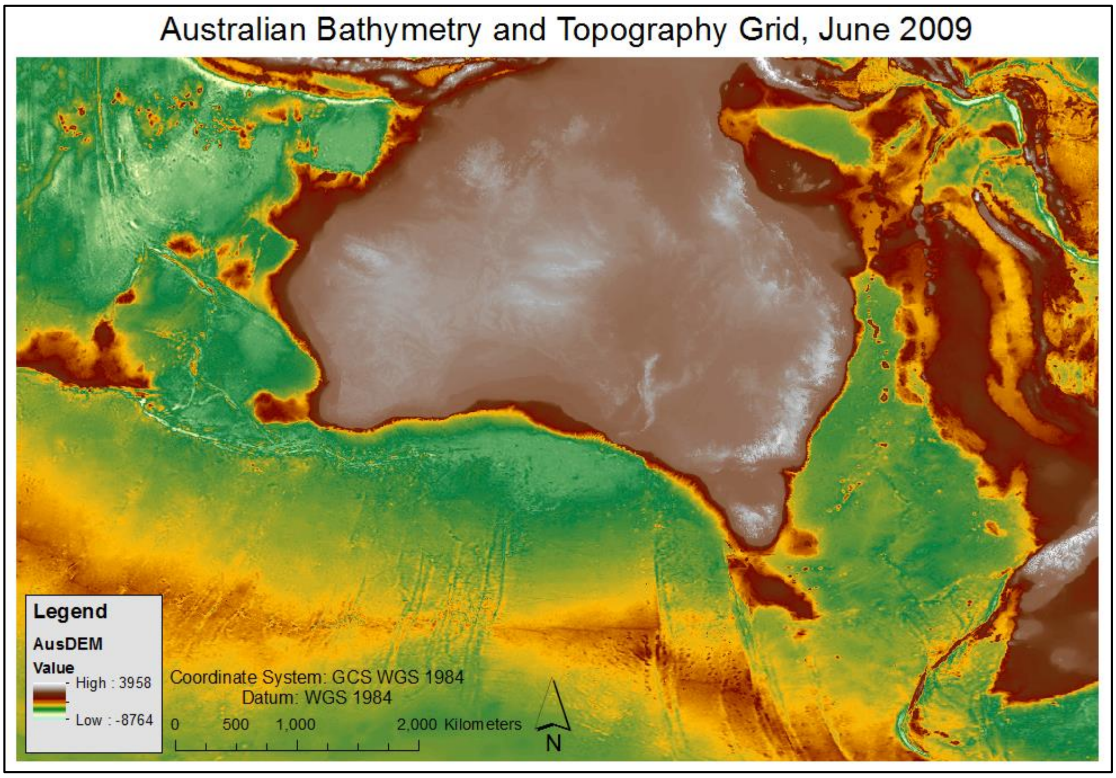


Figure 3.2: The Australian Bathymetry and Topography Grid, June 2009 dataset (Geoscience Australia 2019).

3.2.1 Study Area Extent

For modelling purposes, the AusDEM was clipped to present the data for the state border of South Australia using the State and Territory Digital Boundaries feature class produced by the Australia Bureau of Statistic (2017) (feature class layer renamed Australia_States_2016). The process involved creating a rectangular polygon of the South Australian state boarder over the Australia_States_2016 layer using the draw function; the rectangle included the South Australian submerged continental shelf. The polygon was then converted from a graphic to a feature within the draw function. Using the clip function found in the Data Management toolbox, the AusDEM was clipped to the extent of the South Australian polygon creating a new raster layer (SA_DEM) (Figure 3.3). This method was also used for other raster and polygon data obtained through the desktop survey related to South Australia.

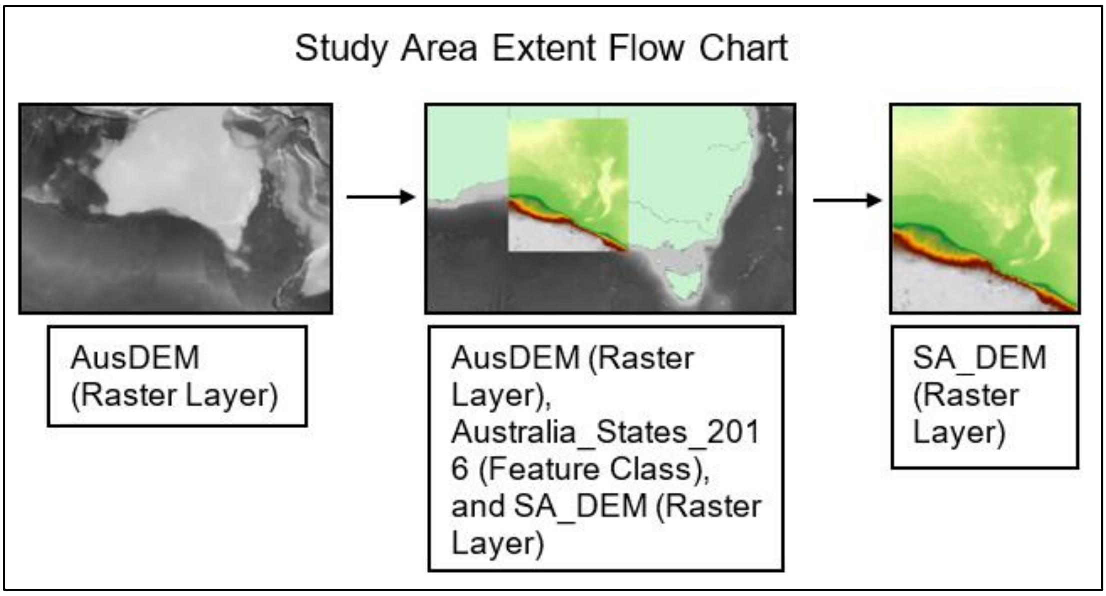


Figure 3.3: Study area extent flow chart.

3.2.2 Modelling Approaches

To model topographic changes, several forms of visual manipulations and data inquiries were conducted on the SA_DEM.

3.2.2.1 Symbology

Various changes to symbology were undertaken to determine the appropriate visual display. The first was the classification of the data to show the extent of the continental shelf at various sea level depths corresponding with exposed land irrespective of terrestrial features (Figure 3.4, insert a). The second was the stretching of the SA_DEM values along a continuous colour ramp. This was done for all values of the dataset and values between 1434 m and depths corresponding with sea level fluctuations at 1,000-year intervals (maximum –130 m) (Figure 3.4, insert b and Figure 3.4, insert c). This method was also conducted a third time, however, the colour ramp used was changed to exaggerate bathymetric features, only for values between 0 and depths corresponding with sea-level fluctuations (Figure 3.4, insert d). These methods were used to test the best way to display the data.

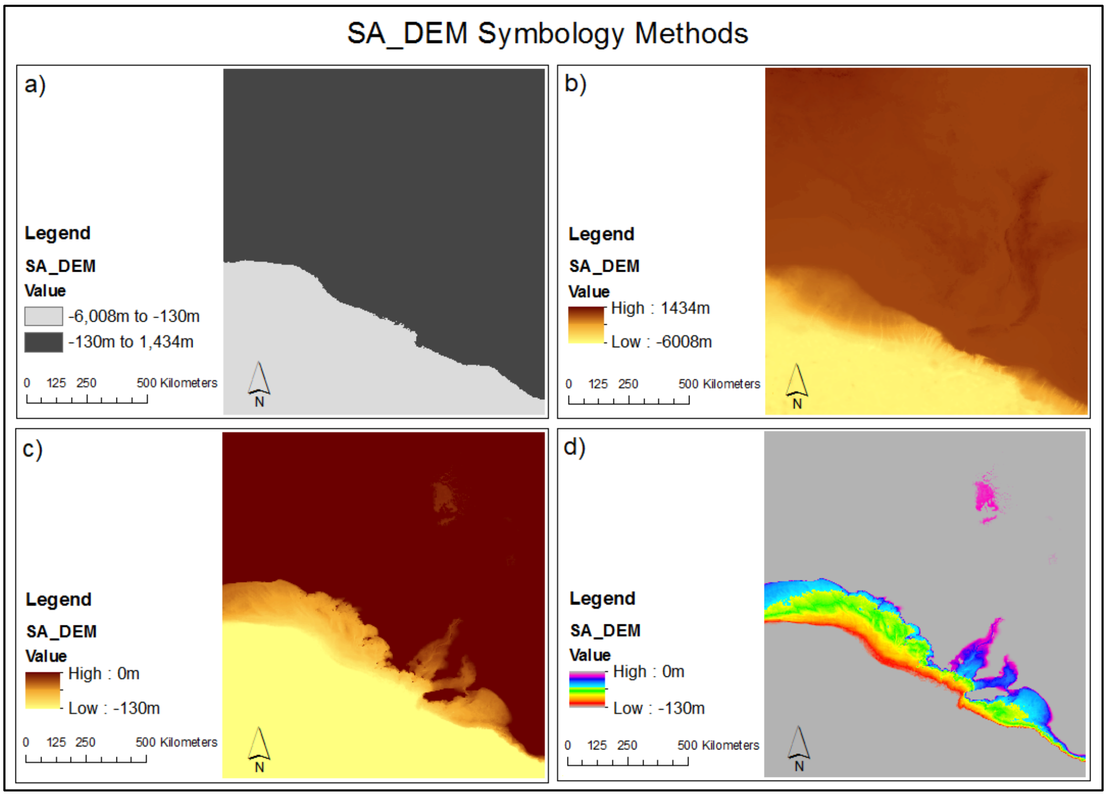


Figure 3.4: SA_DEM symbology method outputs.

3.2.2.2 DEM Clarification

After testing symbology, it was decided to test if there was any difference to the SA_DEM when it was confined by the attributes available to use. Therefore, new DEM layers were created corresponding with sea level depths at 1,000-year intervals. These layers were created using the extract by attributes feature in the spatial analyst toolbox within ArcMap (Figure 3.5). When prompted, the SQL clause used to dictate the values to select was:

Value BETWEEN –__ AND 1434

After each new DEM was created, the symbology method demonstrated in Figure 3.4, insert b was used to display the data constrained to each individual DEM. Moreover, an additional stretch function was applied to the final colour ramp in order to display changes of only those values below 0 m. This was to ensure display of features above

0 m remained relatively unchanged. The method involved applying a gamma stretch to the data, where the values dictated the contrast of the dataset, affecting only the middle values (ESRI 2017). The gamma stretch was eyeballed with values between 1.5 and 2.6 (Figure 3.6). A base polygon was placed under the new extent to distinguish further between the modelled area and the non-modelled area (water body).

After modelling, radiocarbon dated sites were placed into their corresponding time periods, determined using date proximity. This was done by importing the local coordinates into ArcMap, as an excel file. Singular and multiple sites were selected to be displayed within the layer properties > symbology. This was done to display archaeological sites to inform assessment of significance of submerged continental shelf for South Australia; as an identification of Pleistocene terrestrial sites in their primary context.

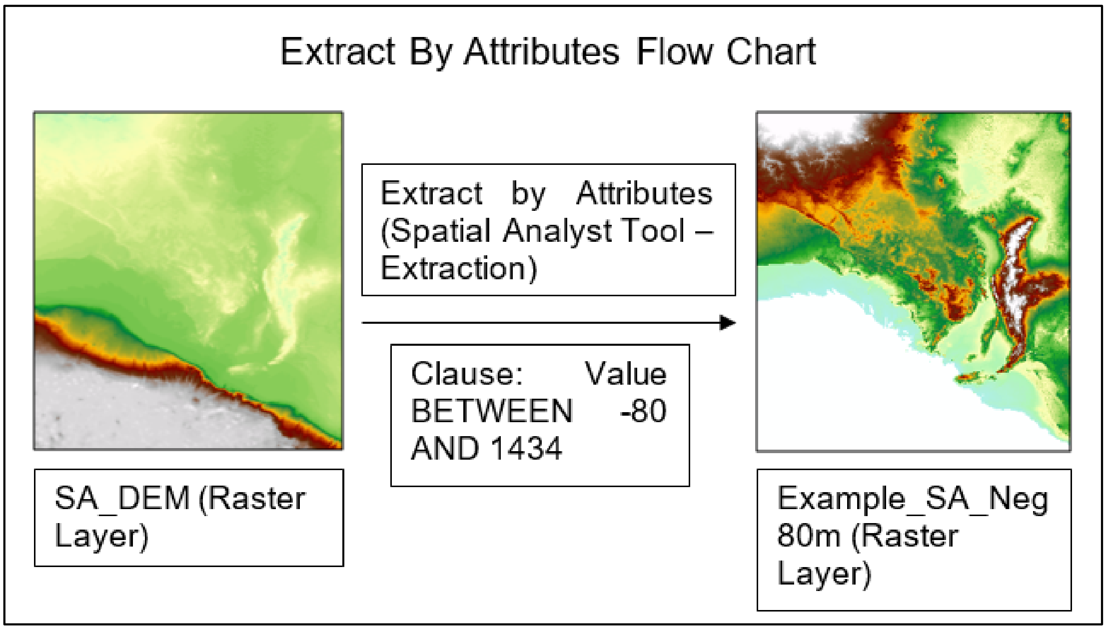
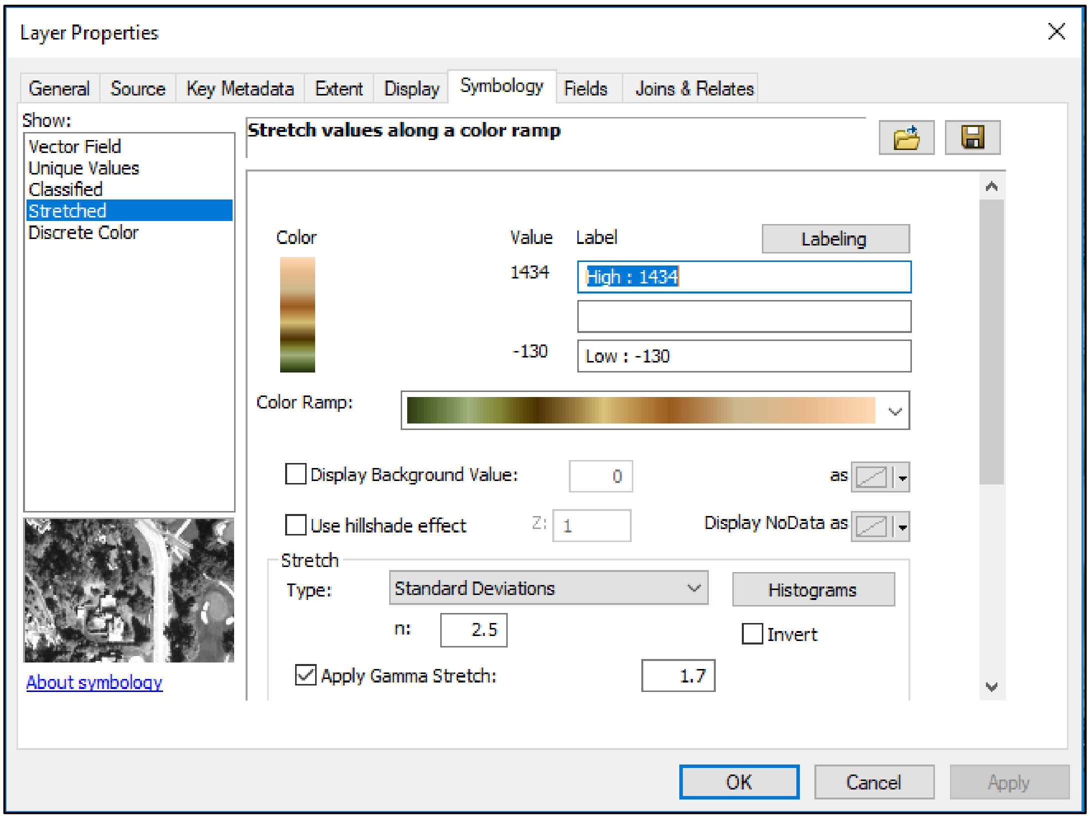


Figure 3.5: Extract by attributes flow chart.



Show: Stretched

Stretch values along a color ramp

Color	Value	Label
	1434	High : 1434
	-130	Low : -130

☐ Display Background Value: 0

☐ Use hillshade effect Z: 1

Display NoData as

Stretch

Type: Standard Deviations

n: 2.5

☐ Invert

☑ Apply Gamma Stretch: 1.7

Figure 3.6: Raster grid gamma stretch.

3.2.2.3 Hydrological Modelling

Hydrological modelling was used to analyse changes to topography potentially caused by fluvial processes. The modelling process enabled the prediction of drainage systems of the current terrestrial landscape and that of the submerged continental shelf. The hydrological models were initially created for the DEMs of each 1,000-year interval to show the relationship between sea-level fluctuations and drainage systems. However, a hydrological model corresponding to the lowest sea-level regression was deemed adequate for display and interpretation purposes (see section 4.2.2). The hydrological modelling followed the methods outlined by ESRI (2016) and Vieux (2016:117) (Figure 3.7).

The first step in the modelling process involved identifying any issues with the DEM concerning the creation of a flow direction layer. This process involved using the fill tool to fill in any depressions or sinks which could cause problems for the model further along. This fill layer was then used to create the flow direction layer, which determines the direction of water flowing out between cells. The output was then used to create a flow accumulation layer. The flow accumulation layer was used to create the stream network (predicted drainage systems), where the layer is used to 'calculate the number of upslope cells flowing to a location' (ESRI 2016). A threshold was placed on the flow accumulation output layer, which was conditioned (con tool) by the flow direction layer for both true and false raster values. No SQL expressions were used in order to create a close to true evaluation of stream networks. Next the stream order tool was used to determine the 'order of each of the segments in a network', the network being the flow accumulation (ESRI 2016). The output of this step was then transformed into a feature class using the stream to feature tool. The stream feature class was then constrained in the layer's properties to only show those line features of a higher weighting (using the Definition Query function).

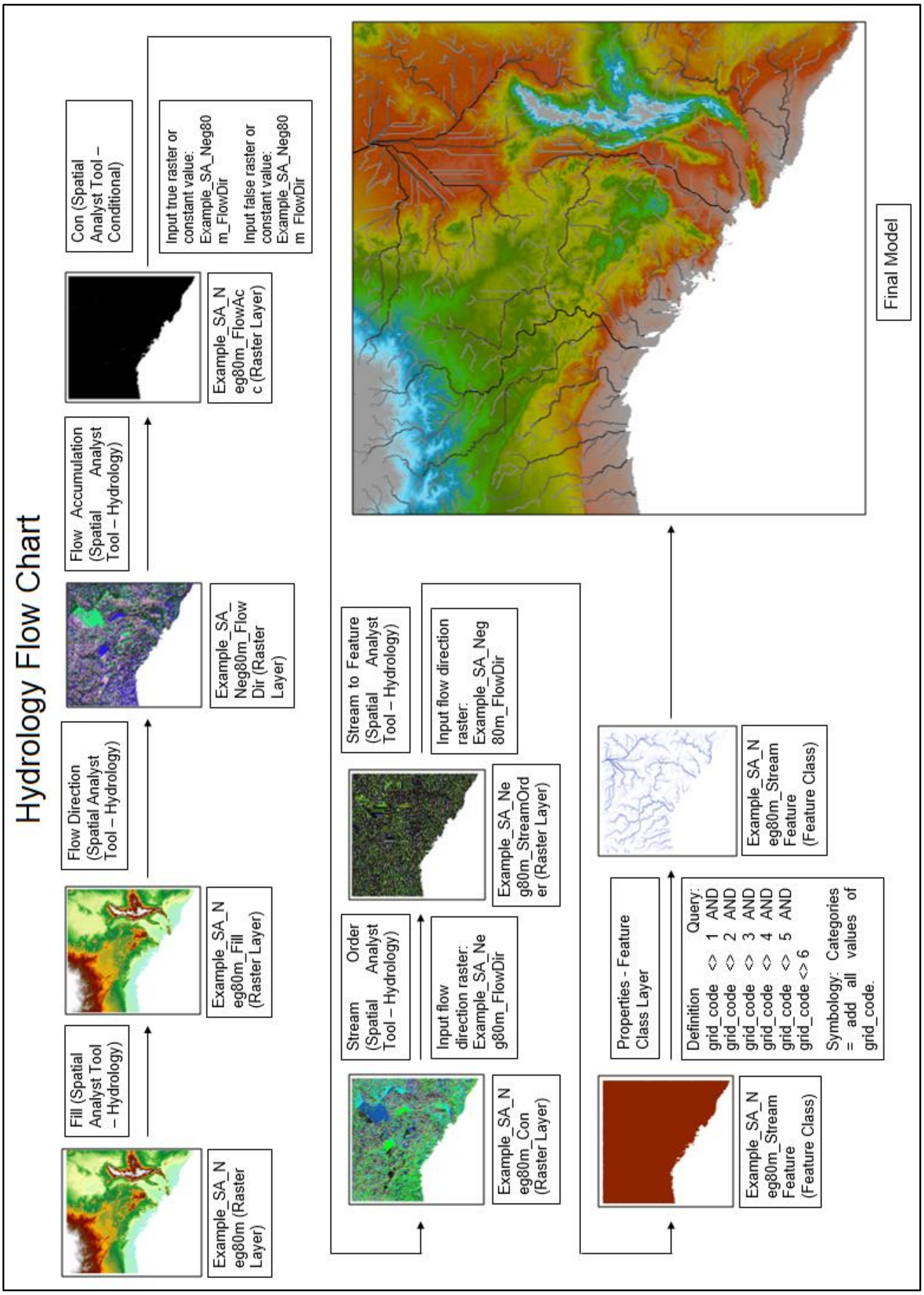


Figure 3.7: Hydrology flow chart.

3.2.2.4 Topographical Modelling

Topographical modelling was used to distinguish potentially identifiable terrestrial landform features on the submerged continental shelf; in conjunction with the 2006 geomorphic features dataset produced by Geoscience Australia (see Heap et al. 2006; Heap and Harris 2008) and the results presented in section 4.1. This was done to add to the interpretation of landscape context and changes. The methods employed were those set by Weiss (2001) and Jenness (2006); that is the concept of Topographic Position Index (TPI). Weiss (2001) first introduced the process in a poster for the 2001 ESRI User Conference. TPI 'compares the elevation of each cell in a DEM to the mean elevation of a specified neighbourhood around that cell' (Weiss 2001). TPI values which classify as positive within the defined neighbourhood are higher than those surrounding values; the reverse occurs for a negative value (Weiss 2001). The results of positive values indicate potential ridge and hilltops, whereas negative values tend to indicate valley and canyon bottoms (Figure 3.8 and 3.9) (Weiss 2001). TPI values which classify as near zero tend to indicate areas of flat plains or areas of constant slop (Weiss 2001).

Using this method, Jenness (2006) went further to create a GIS extension tool available to the public for application to their own data. This study utilised an updated version of this tool, available for use as an ArcGIS toolbox extension created by Dilts (2017). The process involved adding the toolbox to ArcMap, then inputting the relevant DEM. In this case, both the DEM for of the whole study area (1434 m to –130 m) and just the continental shelf (0 to –130 m) were tested, with the latter providing the greatest detail, with reduced data input into the algorithm. After multiple testings, the calculated neighbourhood was set to radius and a cell size of 30 was chosen as the neighbourhood area (Figure 3.10). The cell size of 30 was chosen for the level of detail it provided, considering the broader area. Large cell sizes provided less detail whilst smaller cell sizes created an excess of detail which could not be analysed.

To aid in the identification of these features, 2D profile graphs were created using the ArcMap toolbar extension 3D Analyst (ESRI 2018). The tool used was the interpolate line function. Once a line was drawn over a feature, the profile graph function was selected. The result was a profile graph representing the heights of features along that line (Figure 3.11). The system used to define features were those set by Speight (2009:31–44, 55–72) and Pain et al. (2011:4).

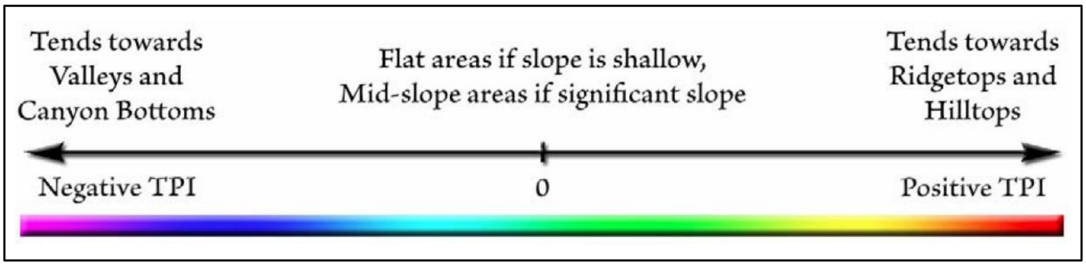


Figure 3.8: TPI scale bar (Jenness 2006:4).

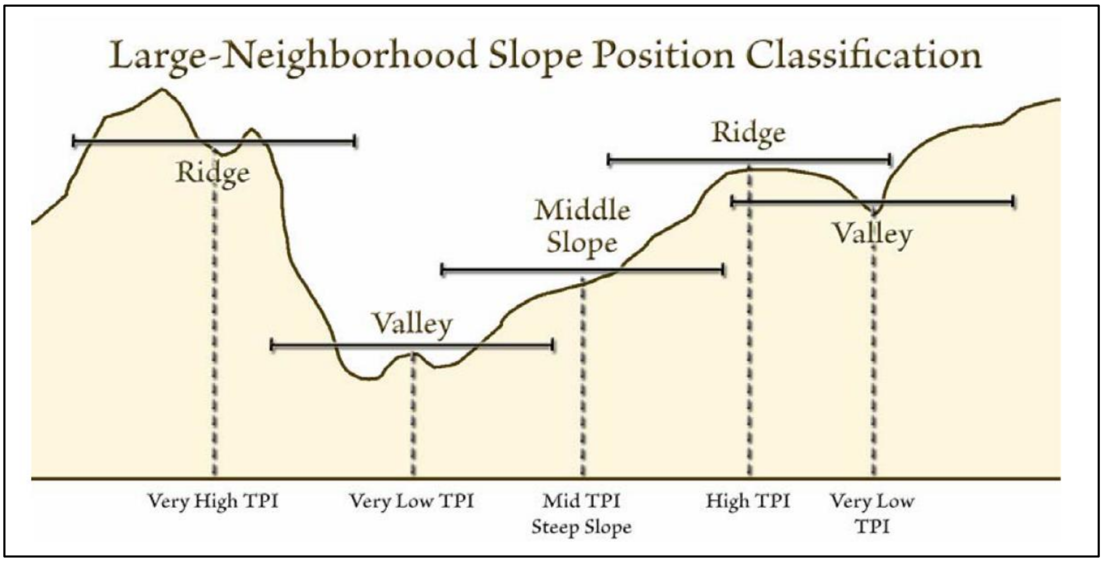


Figure 3.9: Large-neighbourhood classification example (Jenness 2006:7).

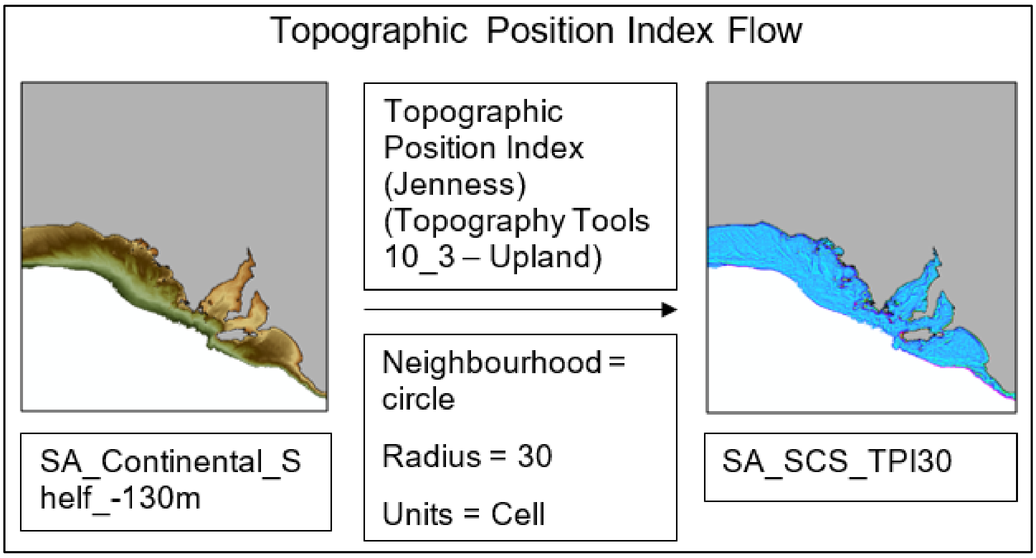
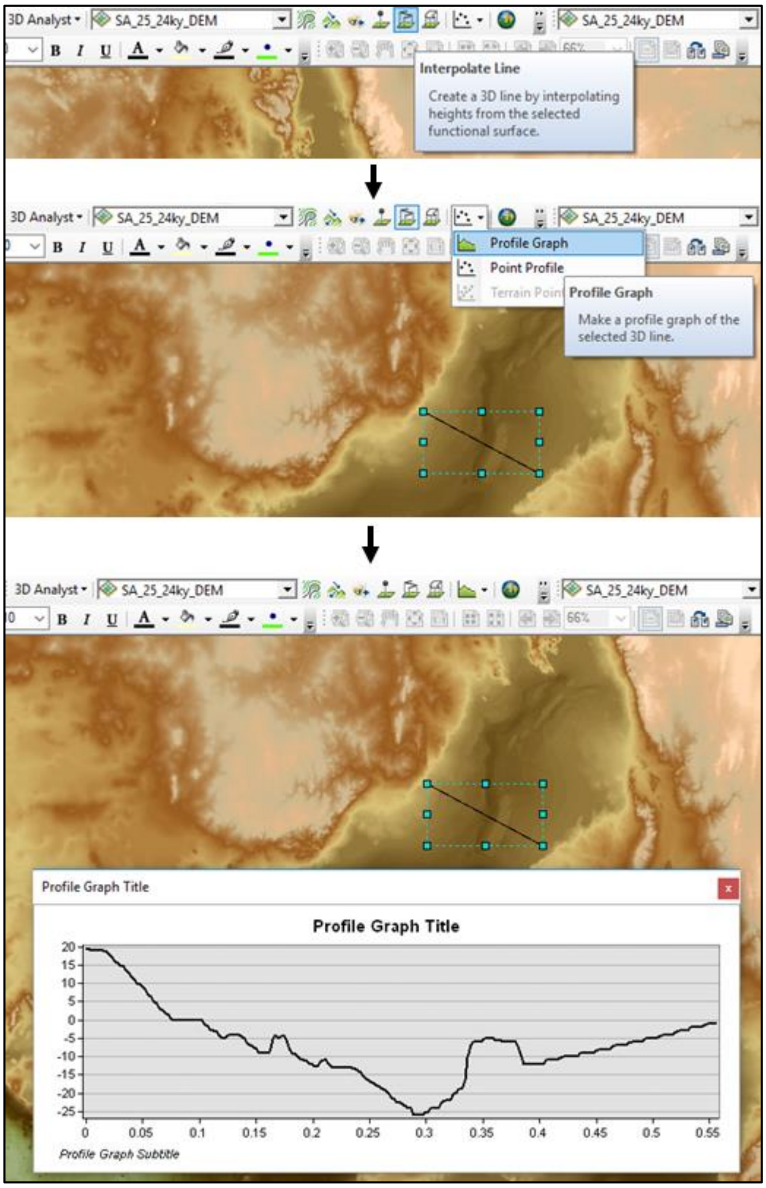


Figure 3.10: Topographic position index flow chart.



Interpolate Line

Create a 3D line by interpolating heights from the selected functional surface.

Profile Graph

Make a profile graph of the selected 3D line.

Figure 3.11: Profile graphs method.

3.3 Summary

This chapter presented the two methods utilised within this study: desktop survey and landscape modelling. Both were conducted as complementary methods to the investigation of geomorphic processes to ascertain topographical changes and circumstantial context for South Australia for archaeological purposes. The subsequent chapters detail the results of the methods and analysis of these changes.

Chapter 4: Results

This chapter presents the results of the desktop survey and the landscape modelling outlined in the previous chapter. The results for the desktop survey present the effects of geomorphological processes on the topographical evolution of South Australia. The landscape modelling results present visual representations of this evolution. The modelling results are presented so that the information obtained in the desktop survey is used to help interpret the models for the purposes of analysing significance to the archaeological discourse (Chapter 5).

4.1 Desktop Survey

The desktop survey identified three geomorphological processes affecting the topography of the South Australia over the last 50,000 years. These processes were identified as aeolian, fluvial, and marine. Of these processes, marine and fluvial presented as the major processes and are discussed in relation to sediment production and deposition. Due to the nature of the investigation, focusing on the submerged continental shelf, aeolian processes were not included in the data process. This is due to the nature of scale for this study, whereby the effects of aeolian processes to topography have minimal impact on the results of landscape modelling. However, mention is made here to the effects of sea-level fluctuations on the changes to the subaerial exposure of the submerged continental shelf in the Late Pleistocene. In the Spencer Gulf region, sea-level fluctuations saw changes in the subaerial exposure of the topography, with the establishment of ‘a central playa or saline lake environment surrounded by progressively encroaching marginal clay and gypsum dunes, and alluvial plains or distal alluvial fans’ (Gostin et al. 1984:176; Gostin and Hill 2014:28;

Murray-Wallace 2014:281). The same occurred for Gulf St Vincent, with the area forming a dry plain landform of calcreted sediments and featured a central saline lake towards the end of the Late Pleistocene; with the lake flooding by 11,000 and 9,000 years BP (Cann et al. 1993:202–207; Fuller and Gostin 2008:29). Continued transgressions and regressions of sea meant the drainage of Gulf St Vincent to the extent of total drainage, or the creation of Lake St Vincent (McGowran and Alley 2008:25). On the inner to outer exposed shelf areas, the former were areas of shallow, semi-isolated marine lagoons and bays, with the latter as an extensive plain area (Li et al. 1996:309; Li et al. 1999:117). Again, subaerial exposure similar to the gulf regions occurred for the Lincoln Shelf (Li et al. 1999:117).

4.1.1 Marine Processes

Marine processes are the main contributors to topographic changes of South Australia. The processes occur 1) from the result of sea-level regression and transgression due to glacial cycles, and 2) physical processes of current circulation, tidal regimes and surface waves (Holocene).

4.1.1.1 Sea-Level Fluctuations

The nature of Late Pleistocene and Holocene sea-level fluctuations has been a major focus within both palaeoenvironmental and archaeological studies around the world. The main cause of these sea-level changes is primarily related to the formation and deterioration of glaciers; the impact resulting to changes in the volume of water in the worlds ocean (glacioeustasy), or to the structure of the lithosphere (glacial isostasy) (Lambeck 2009:374; Lewis et al. 2013:115; Pekar 2009:354). The areas in which these changes occur are known as far- and near-field areas, respectively (Fleming et al.

1998:327; Lambeck et al. 2014:15297). Far-field areas are located furthest from glaciated areas where effects of glacioeustasy were greater in the past (Lambeck et al. 2014:15297). Near-field areas are located in close proximity to former glaciated areas where effects of glacial isostasy were greater in the past (Lambeck et al. 2014:15297)

South Australia is characteristic of a far-field location. The area was uninfluenced by local glaciation throughout the last 50,000 years, and is located far from past and present glaciated areas (e.g. Antarctica). With South Australia's relative tectonic stability, sea-level fluctuations result primarily from glacioeustasy. There is the potential of hydro-isostasy as outlined by Lewis et al. (2013:116), however the affect is insignificant to warrant further investigation for the period prior to the start of the Holocene for South Australia (see Belperio et al. 2002). As such, discussions of global glacioeustasy were used to provide a record of sea-level fluctuations for South Australia (e.g. Brooke et al. 2017; Chappell and Shackleton 1986; Fleming et al. 1998; Lambeck and Chappell 2001; Lambeck et al. 2014; Lewis et al. 2013). Evidence recorded for glacio-eustatic changes are restricted to those collected in far-field locations for relevance to the study area and reliability in replicable data.

The recorded evidence of sea-level change in far-field areas, for the last 50,000 years, is spread infrequently around the world; both spatially and temporally (Lambeck and Chappell 2001; Lambeck et al. 2014; Lewis et al. 2013; Murray-Wallace and Woodroffe 2014:320–351). As such, studies concerning far-field sea-level data from around the world have been selected, for the Late Pleistocene, rather than from the Australian region, where a higher number of individual data records will provide a greater representation of generalised sea-level fluctuations caused by global glacial formation/deterioration. This is best summarised by Lambeck et al. (2014:15297) where 'most sea-level indicators provide only lower (e.g., fossil coral) or upper (e.g., fossil terrestrial plants) limiting values, and multiple data-type analyses of both upper and lower limiting measurements are less likely to be biased toward one or the other limit'. It is acknowledged here that arguments have been made against the production of a global sea-level curve due to geographical variability in relation to water loading (see Lambeck et al. 2002:350, and Murray-Wallace and Woodroffe 2014:364). However, any changes in the lithosphere due to water loading are generally restricted to Holocene sea-level changes (Lewis et al. 2013:116). Nonetheless, studies continue to use global data for the purposes of modelling sea-level fluctuations in far-field regions and reconstructing palaeoshorelines, where constant similarities are expressed (Brooke et al. 2017:31–35; Fleming et al. 1998; Lambeck and Chappell 2001:684–685; Lambeck 2004:686–688; Lambeck et al. 2014; Lewis et al. 2013:123–125; Williams et al. 2018:148). Where Holocene sea level is concerned only data from South Australia has been used; this data being abundant for the time period, and is used as a means of presenting observed 'geographical variability in relative sea-level change during the Holocene' (Murray-Wallace and Woodroffe 2014:364).

The selected far-field studies for the Late Pleistocene are those by Lambeck (2004, after Lambeck and Chappell 2001 and Lambeck et al. 2002), and Lambeck et al. (2014). South Australian Holocene sea-level data is presented by Belperio et al. (2002). All data points and associated sea-level curve are presented in Figure 4.1. See section 4.2.1 for visual presentation of sea-level fluctuations and associated landscape changes for South Australia. Lambeck (2004:679) was chosen for his summarisation of mean sea level, for pre-35,000 years cal. BP, between expected upper and lower sea-level limits from Lambeck and Chappell (2001) and Lambeck et al. (2002). These observed relative sea levels were retrieved from the Huon Peninsula in Papua New Guinea, and create the most complete record of sea level for this time period. The sea level recorded for this period depicts a trend of relative regression due to increase in global ice content (Figure 4.1).

Data presented by Lambeck et al. (2014:15296–15298) was used for its comprehensive collection of far-field sea level records from the period between 34,000 to 8,000 years cal. BP. Data was collected from tectonically stable regions (where possible), and from both sediment and coral records (Lambeck et al. 2014:15297–15298). All evidence was dated using radiocarbon or uranium-series (Lambeck et al. 2014:15297). The data presented by Lambeck et al. (2014:15298) is used with caution due to the discrete absence of potential outliers, mainly throughout the period between 8,000 to 15,000 years cal. BP. However, this observed absence is deemed acceptable here, until such time that data for South Australia, for this period, is obtained. The sea level recorded for this period depicts three trends of fluctuations. The first is a rapid regression period seen between 34,000 to 31,000 years cal. BP. The second trend is a stabilisation of sea level between 30,000 to 17,000 years cal. BP. The final trend is the rapid transgression of sea level between 16,000 to 8,000 years cal. BP. All trends were caused by the changing climatic regimes throughout the past, between a cold and dry climate, to a warm and wet climate (present).

Sea-level data presented by Belperio et al. (2002:153) was used for its comprehensive collection of evidence of Holocene sea-level records for South Australia (restricted to the last 10,000 years cal. BP). Samples were collected primarily from regions within the Spencer Gulf and Gulf St Vincent, as well as from the northern Great Australian Bight (Ceduna) (Belperio et al. 2002: supplementary data). The data represents a collection of upper and lower limiting sea-level values which, as with Lambeck et al. (2014) creates an overall indication of past sea levels (Belperio et al. 2002:158). The sea level recorded depicts a second stabilisation period.

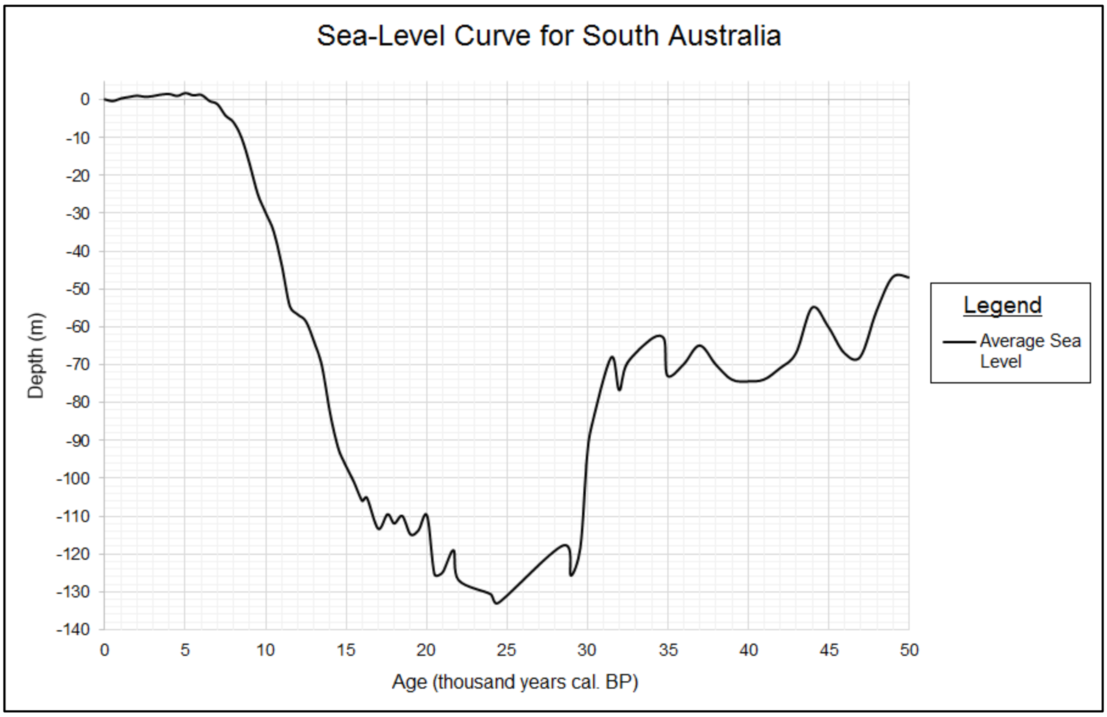


Figure 4.1: Sea-level curve produced using observed sea-level data from Belperio et al. (2002), Lambeck (2004) and Lambeck et al. (2014).

As a result of the fluctuating sea levels, minimal terrestrial sediment deposition occurred on the South Australian continental shelf. This was predominately over pre-existing Late Pleistocene marine sedimentations dated to the last interstadial period (~120,000 years ago) (Figure 4.2), or the Mesozoic and Early Cenozoic sedimentary basins. Following the last interglacial period, and associated sea-level highstand, a period of gradual sea-level regression occurred. Within this gradual glacial period (~120,000 to 30,000 years BP), marine deposits were characterised by sedimentation occurring on lower lying continental shelf areas (compositional, not stratigraphic deposition) (Belperio 1995b:228; James and Bone 2011:25). Record of those sedimentary formations are only present in the gulf regions, and are comprised of the False Bay Formation and the Lowly Point Formation, along with an unnamed oxygen isotope stage 3 formation (Figure 4.2) (Belperio 1995b:228). The False Bay and Lowly Point formations are from periods of transgressions occurring ~105,000 and ~80,000 years BP respectively, and are comprised of calcareous clay and quartz sand (Belperio

1995b:228; Hails et al. 1984:352). The unnamed stage 3 formation was produced from the regression occurring between ~45,000 and 30,000 years BP and comprises of unlithified calcitic mud (Belperio 1995b:228; Murray-Wallace 2014:282). Of the minimal Late Pleistocene marine sedimentation, composition is wholly biogenic, and comprises mainly of bryozoans and benthic foraminifera, forming the limestone sedimentary geology of South Australia (James et al. 2001:553). These organisms provide not only sedimentation, but indication to the terrestrial and early marine environments through regression and transgression.

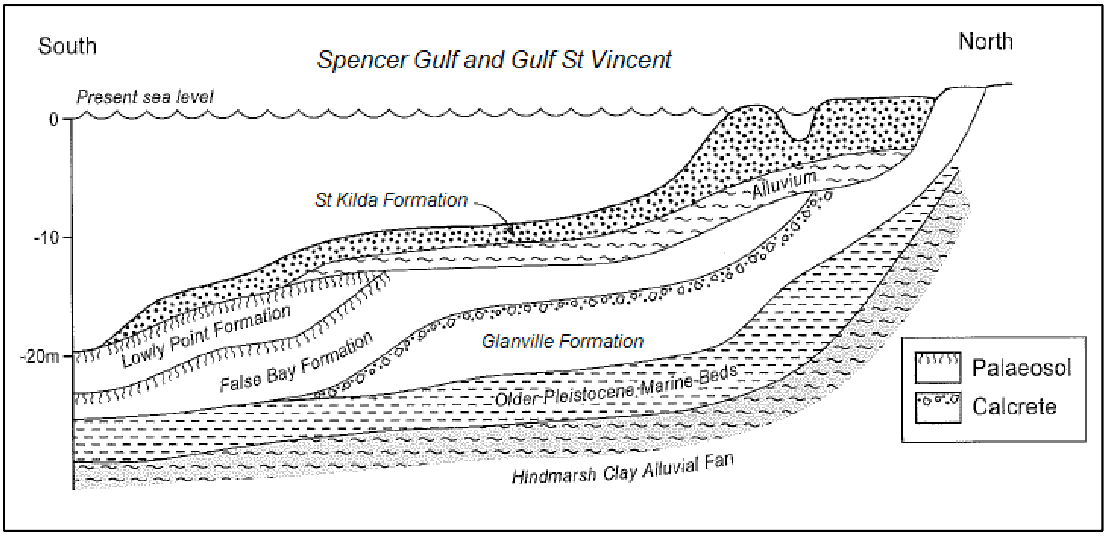


Figure 4.2: Late Pleistocene and Holocene sedimentation strata from South Australia; Spencer Gulf and Gulf St Vincent (after Murray-Wallace 2014:282).

Holocene marine sedimentation on the continental shelf of South Australia encompasses one deposition strata, referred to as the St Kilda Formation, and was influenced by past Late Pleistocene geological processes and post LGM sea-level transgression (Belperio 1995b:230; James and Bone 2011:25). The St Kilda Formation, found primarily in the gulfs and the Lacepede Shelf, is comprised of biogenic carbonates, and contains remnants of Pleistocene sediment particles (Belperio 1995b:230–231; James and Bone 2011:25). This sedimentary composition also occurs along the Great Australian Bight (Richardson et al. 2005:64). This

Holocene sedimentary deposit conforms to the profile of underlying Pleistocene deposits (James and Bone 2011:25; Gostin et al. 1984:167,177–178).

In the Spencer Gulf, the St Kilda formation varies in thickness, with sediments recorded on average at no more than 2 m (Gostin and Hill 2014:28); though 4–6 m is recorded in the upper gulf region, with these sediments not occurring through the processes of an intertidal environment (Belperio et al. 1984:302). Marine sediments indicate Holocene deposition beginning at 7,000 and 6,000 years BP (Belperio et al. 1984:302). This is the same circumstance for Gulf St Vincent, where the deposit is between <1–2 m (Belperio et al. 1988:494; Cann et al. 1993:207; Fuller and Gostin 2008:29). The complexity of the marine Holocene sedimentation over the Lacepede shelf is quite extensive (up to 8 m) in comparison with the gulf regions (Figure 4.3) (Hill et al. 2009:144). This is in part due to the Late Pleistocene outlet of the Murray River (see section 4.1.2) (Hill et al. 2009:135).

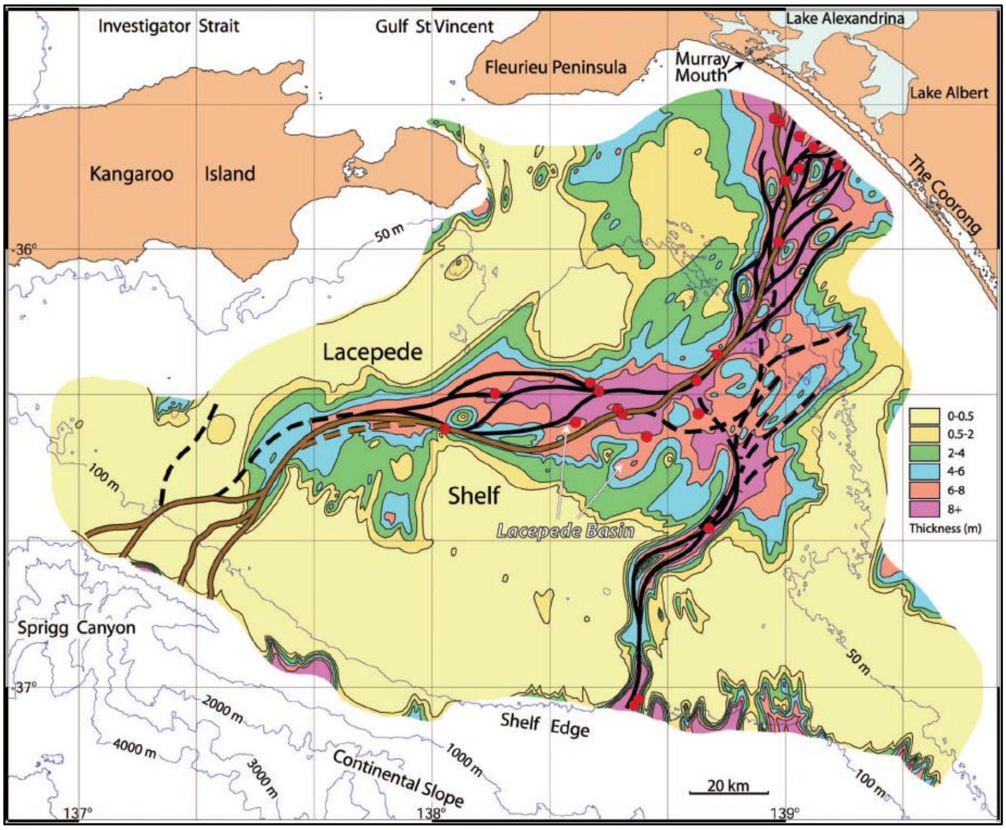


Figure 4.3: Lacepede Shelf Holocene sedimentation accumulation in Ancient Murray River Basin, with direction of palaeochannels (LGM) (Hill et al. 2009:144).

4.1.1.2 Current Circulation

The current circulation exhibited in South Australia is comprised of two main regimes. These two regimes are defined by their location, the first restricted to the exposed shelf areas and the second restricted to the gulf regions. The first regime is the movement of water across the exposed shelf area consisting of the Great Australian Bight, the Lincoln Shelf, the Lacepede Shelf, and the Bonney Shelf. This exposed shelf area has two major current systems which operate upon them; they are the Flinders Current and the South Australian Current; the latter referred to as the Great Australian Bight current in the Great Australian Bight region (James and Bone 2011:20–22; Murray-Wallace 2014:278) (Figure 4.4 and 4.5). The Flinders Current resides in the middle waters above the continental slope but below the South Australian Current, and moves onto the west shelf region when the Leeuwin Current weakens during the summer (James et al. 2001:550; James and Bone 2011:21). The cool-water current flows west in the summer and east in the winter, with directional flow originating east of Tasmania, travelling west parallel to the Australian continent (Bye 1983:79; James and Bone 2011:15, 20–21; Murray-Wallace 2014:278). The warm, saline South Australian Current is an east travelling current forming in the west off the west of the Great Australian Bight in summer/autumn; merging with the end of the Leeuwin Current (Seen in Figure 4.4 as the Great Australian Bight Current) (James et al. 2001:550; James and Bone 2011:22). The South Australian Current contributes to the majority of oceanographic characteristics of the Bonney Shelf (e.g. salinity, temperature etc.) (Bye 1983:80).

The interplay between the two currents, in relation to seasonal winds, sees downwelling as the most prominent water mixing occurring in the exposed shelf regions for nine months of the year (James et al. 2001;550; Murray-Wallace 2014:278;

Richardson et al. 2005:60). Upwelling usually occurs in the summer months, when the current systems are at their weakest (James et al. 2001:550; James and Bone 2011:22; Murray-Wallace 2014:278). Upwelling brings cool, nutrient-rich waters of the Flinders Current to the exposed shelf, feeding sediment production (Richardson et al. 2005:60). Upwelling provides nutrient-rich water to shelf (summer), and downwelling removes sediment, transporting it onto the slope (winter) (Middleton and Bye 2007:3; Richardson et al. 2005:60). Local currents occur close to the coast and influence sea-surface temperatures (James and Bone 2011:143–144).

The second regime is the movement of water within the protected shelf areas consisting of the Spencer Gulf and Gulf St Vincent (Figure 4.5). The gulfs currents flow clockwise all year round and are characterised by accumulation of saline waters in summer due to high evaporation rates (Bye and Kämpf 2008:56; James and Bone 2011:24; Murray-Wallace 2014:279). Output of these saline waters occurs in winter through the process of downwelling, which drives the waters through the mouth of the Spencer Gulf, and to a lesser extent on either side of Kangaroo Island, onto the exposed shelf (Bye and Kämpf 2008:56). During the summer months, this output of water is restricted due to the upwelling experienced on the exposed shelf (James and Bone 2011:154). Due to these saline waters and minimal fresh water input into the gulfs, both are considered inverse estuaries (James and Bone 2011:24; Murray-Wallace 2014:279).

Holocene marine sedimentation over the Eucla Basin are patchy due to these processes affecting Late Pleistocene sedimentation records; the inner and middle shelf is comprised of bedrock with negligible sedimentation accumulation, with the outer shelf moving from a sedimentary state to an exposed bedrock state (James et al. 1994:174; James and Bone 2011:36). Any Holocene marine sedimentation is constantly reworked, with downwelling processes removing most of those carbonate sediments produced during periods of upwelling. The resulting ‘shaved shelf’ is caused by the rate of exchange between a high active erosion rate and a lower carbonate accumulation rate (Figure 4.6) (James et al. 1994:174; Richardson et al. 2005:64). Carbonate production is only seen in areas of nutrient supply (Lincoln Shelf and Lacepede Shelf), occurring mostly in the summer upwelling periods (Hill et al. 2009:141; Richardson et al. 2005:60).

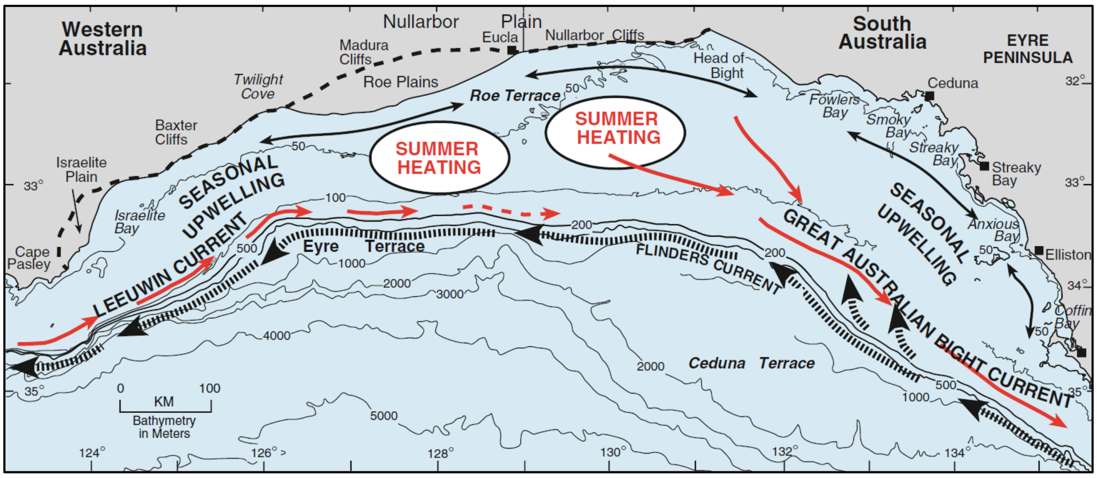


Figure 4.4: Oceanography of the Great Australian Bight (James and Bone 2011:135).

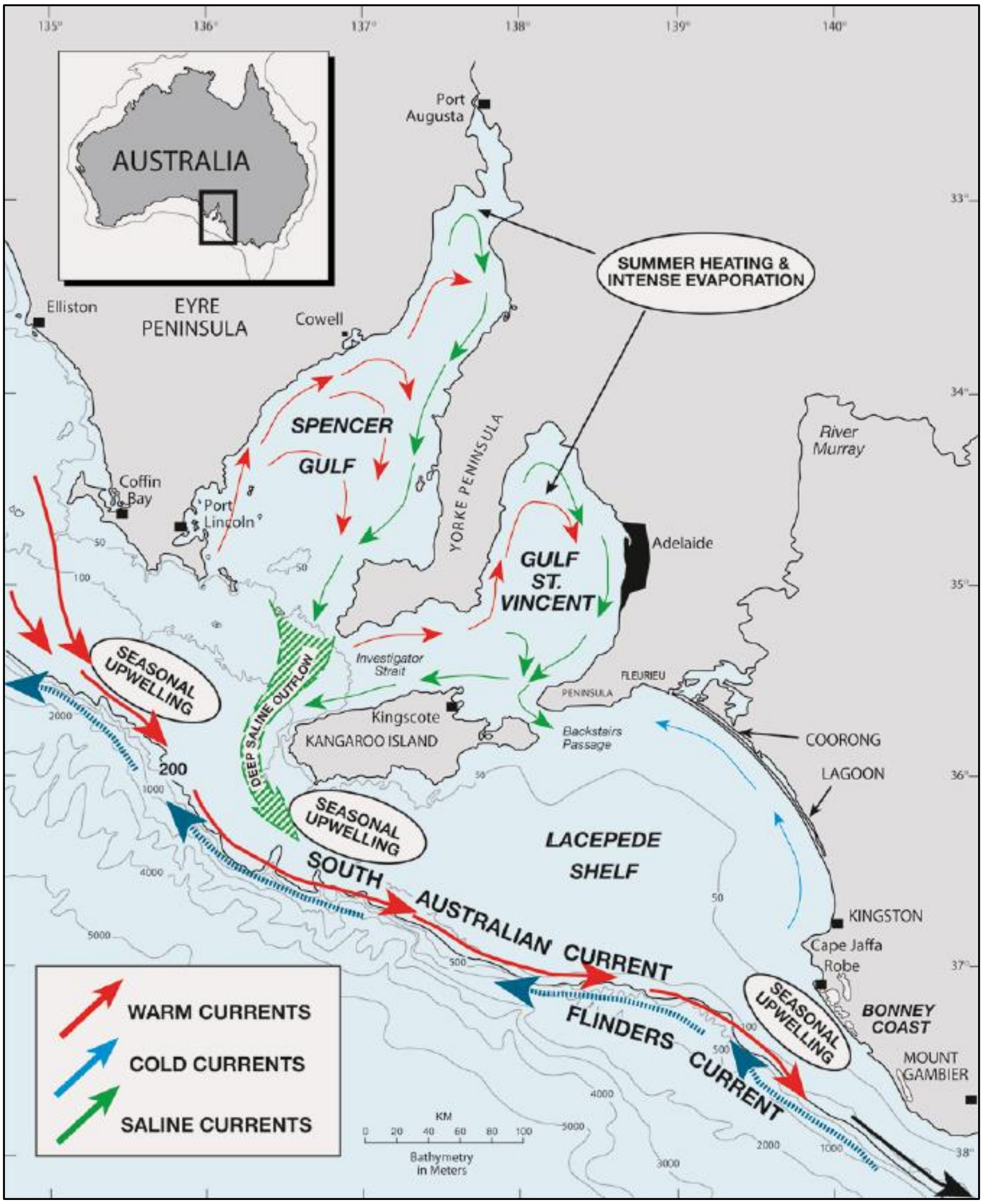


Figure 4.5: Oceanography of the Gulf regions and Lacepede Shelf (James and Bone 2011:151).

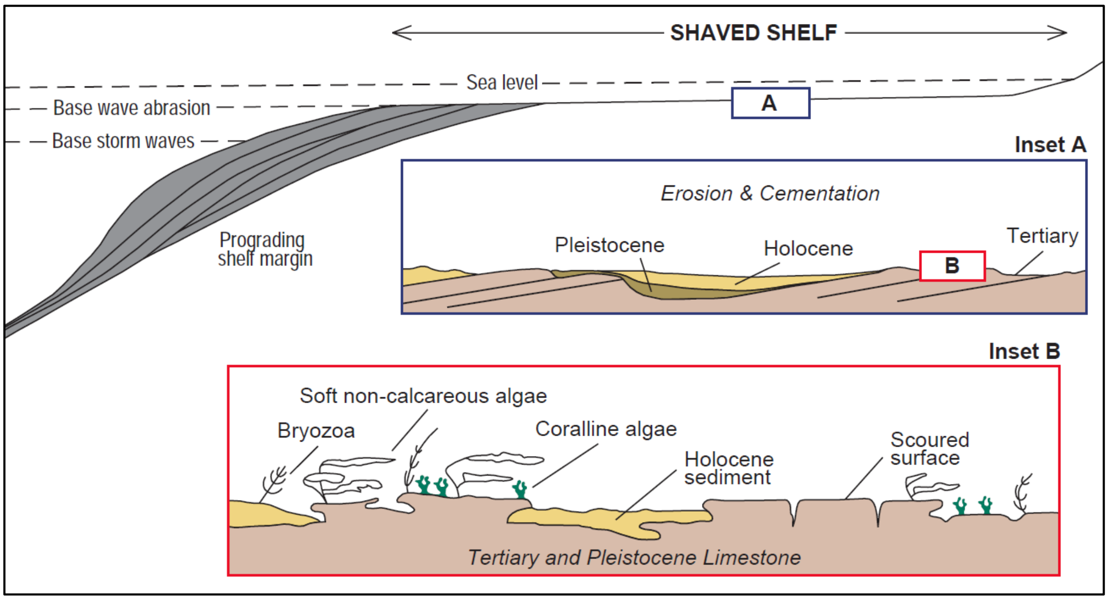


Figure 4.6 Shaved shelf sedimentary elements (Richardson et al. 2005:65).

4.1.1.3 Tidal Regimes and Surface Waves

The South Australian submerged continental shelf oceanographic systems are also characterised by tidal regimes and surface waves; both influencing sedimentation distribution. The South Australian shelf area, except the gulfs, is a region where sediment transport is highly influenced by southern temperate, high energy storms and swells (Murray-Wallace 2014:279; Porter-Smith 2004:3; Richardson et al. 2005:64). Within the gulf regions, the areas are predominately protected, with sediment transport influenced by tidal currents (Porter-Smith 2004:3).

Both gulf systems exhibit similar tidal regimes, where the ‘tidal range increases progressively inland towards the heads of these gulfs’ (Murray-Wallace 2014:279). Both are predominately semi-diurnal tides, with components of diurnal tides adding to periods of dodge tides (periods of no or minimal tidal regimes throughout a 24-hour lunar period) (Bye and Kämpf 2008:57–59; James and Bone 2011:154,156). The Gulf St Vincent’s semi-diurnal constituents (M_2 and S_2) have remarkably similar amplitudes (same levels of tides occurring twice a day) (Bye and Kämpf 2008:57;

James and Bone 2011:154). The Gulf St Vincent experiences tidal ranges of ~2 metres, with Spencer Gulf ranging up to 4 metres (James and Bone 2011:154,156). Within Gulf St Vincent, littoral drifting of restricted costal erosion products occurs due to tidal and wave actions (Shepherd and Sprigg 1976:161).

Wave heights (swell induced) for the regions are presented in Figure 4.7. Wave heights along the Southern Australian exposed shelf are significant, higher than 3.5 m for 30–50% of a 12-month period (Bye and Kämpf 2008:63; Porter-Smith et al. 2004:2–3). Swells predominately originate from the southwest, with the highest force of wave energy occurring on the west coast of the Eyre Peninsula (Richardson et al. 2005:64). 'Swell and storm waves from the Southern Ocean influence the seafloor down to depths of 120 m' (Richardson et al. 2005:64). Wave magnitudes are high along the Lacepede Shelf, with 'the magnitude of incident wave energy decreas[ing] further along this coastline due to the steeper gradient of the inner shelf', towards the Bonney Shelf (Murray-Wallace 2014:279). The gulf regions exhibit mean wave heights of between 0 and 1 metres, particularly along the coast (Bye and Kämpf 2008:62).

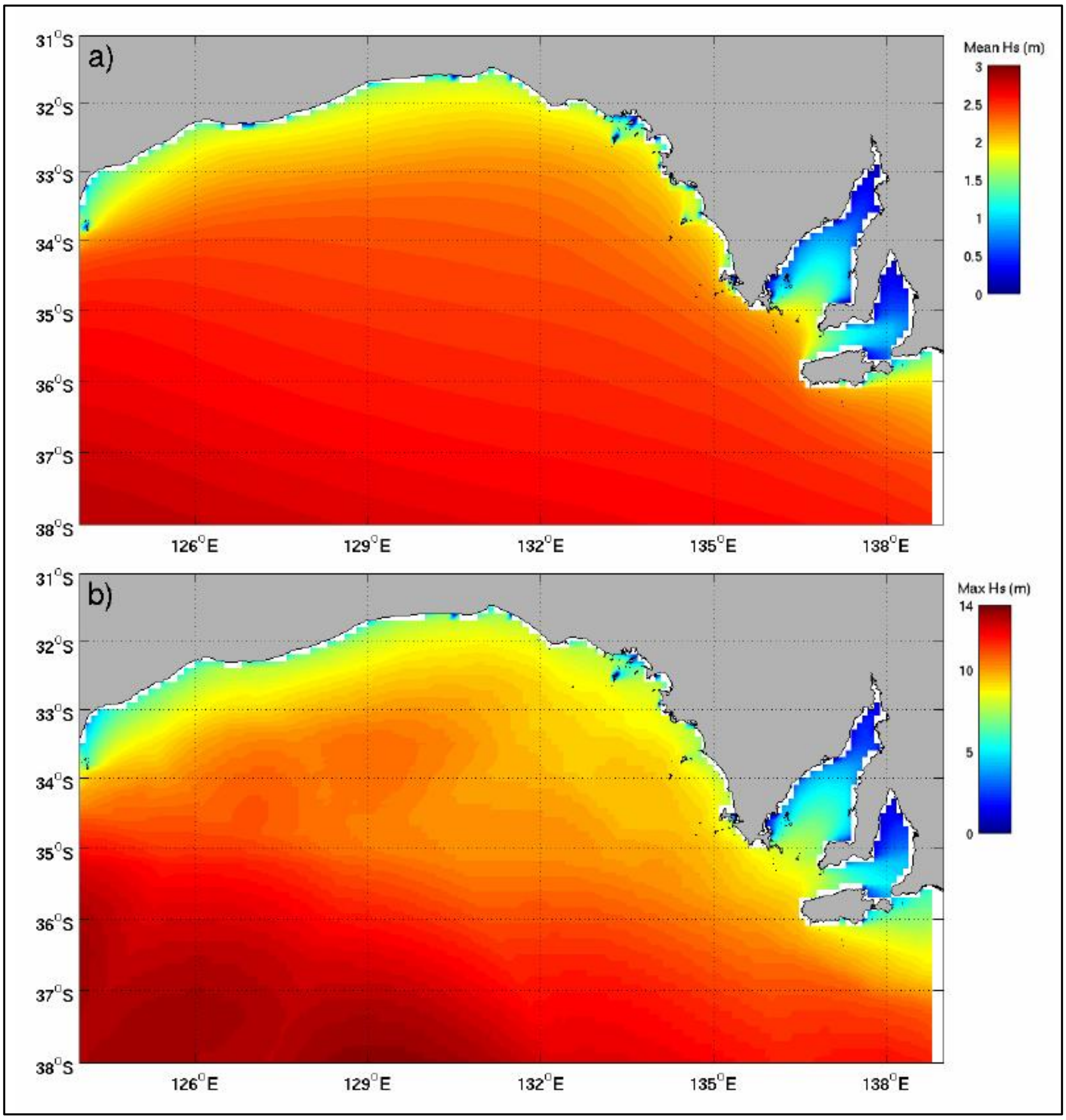


Figure 4.7: Mean (a) and maximum (b) wave height for South Australia (Great Australian Bight and Gulf regions) (Richardson et al. 2005:63).

4.1.2 Fluvial Processes

The majority of fluvial processes exerted on the submerged continental shelf of South Australia occurred on the Lacepede Shelf in the Late Pleistocene and Holocene. The Lacepede Shelf is the termination location of Australia's largest river system, the Murray River. Throughout the Late Pleistocene, during the periods of lowered sea levels, the Murray River would have extended onto the shelf, and would have been surrounded by a vast coastal plain, with featured lacustrine/lagoonal environments

(Hill et al. 2009:135,142). The palaeo-Murray River was up to 1 km wide with depths ranging between 10–20 m (Hill et al. 2009:153). Throughout continuous sea-level fluctuations, the mouth of the river moved across this shelf (Hill et al. 2009:135).

In terms of other fluvial processes, minimal terrigenous sediment supply occurs from the current terrestrial landscape to any part of the exposed or protected shelf areas (Richardson et al. 2005:65; Shepherd and Sprigg 1976:161). The highest terrigenous supply comes from the mouth of the Murray River expelling onto the Lacepede Shelf (Hill et al. 2009:141). Holocene terrigenous sedimentation across the Bonney Shelf has been prevented due to the presence of Last Interglacial Maximum beach ridges which prevent the flow of stream and drainage systems into the ocean (Holmes and Waterhouse 1983:49). However, natural and man-made topographic drainage systems have provided effective drainage of swamps and flats to the sea, this is a relatively slow process (Holmes and Waterhouse 1983:49). The sedimentation output effects of the topographic drainage systems on the submerged continental shelf are unknown. Moreover, there appears to be no recorded sedimentation in the current marine environment from the eruption of Mt Gambier ~5,000 years ago (Belperio 1995c:264; Sheard 1983:9). Terrestrial and marine sedimentation for Backstairs Passage is unknown.

4.1.3 Radiocarbon Calibration

The results of the radiocarbon calibration of dated material from sites within South Australia are presented in Table 1 and Appendix 4. Table 1 displays the rounded mean ages of sites, to be used in conjunction with the landscape modelling. The process involved rounding the mean dates to the nearest whole date corresponding with the modelled time periods of topographic changes (1,000 year intervals). For example, a date obtained for Allen's Cave with a mean age of 9,865 cal. BP (ANU 1040) was rounded to 10,000 cal. BP. Appendix 4 displays all relevant information produced by the radiocarbon calibration. Within Appendix 4, columns display data relating to each individual radiocarbon sample for each site. A total of 65 individual dates were calibrated, 26 by other authors and 39 within this study. The data contained within Appendix 4 are the uncalibrated age and associate error margin, the calibration age range, the mean age (for mapping purposes), the calibration program and atmospheric curve used, and the corresponding reference of the date produced (either external or internal). Where mean dates were not provided by respective authors or through OxCal v4.3, a mean date was determined by finding the average of the upper and lower limiting dates (sum divided by the count). Luminescence dates have also been included for the overall time-series analysis. Errors may be present with the use of differing calibration methods; however, these differences are not deemed sufficient on the time scale of study to warrant further investigation.

Table 1: Calibrated radiocarbon mean ages for archaeological sites in South Australia.

Site Name	Time period (cal. BP)
Allen's Cave	10,000 11,000 14,000 40,000
Balcoracana Creek	10,000 15,000 16,000
Bevilaqua	7,000 9,000
Cape du Couedic	8,000
Cape Martin	10,000

Hawker Lagoon	18,000
JSN Site	12,000 16,000 17,000 18,000
Koonalda Cave	17,000 19,000 23,000 25,000 26,000
Koongine Cave	9,000 10,000 11,000
Mt Burr	8,000 10,000
NE Madigan Gulf	22,000
Roonka Flat Dune	7,000 8,000 22,000
Seton Rockshelter	11,000 12,000 13,000 16,000
Warratyi	25,000 26,000 30,000 33,000 36,000 39,000 40,000 48,000
White Crossing	14,000
Wyrie Swamp	9,000 10,000 12,000

4.2 Landscape Modelling

4.2.1 Discrete Landscapes

The results of the landscape modelling of the SA_ DEM produced, to reflect the topographic changes caused by sea-level changes occurring over the last 50,000 years, are presented in Appendix 5a. These changes are presented in 1,000 year intervals, corresponding with the sea level records of section 4.1.1.1, and are analysed within section 5.1 in terms of a South Australian topographic narrative and section 5.2 in terms of archaeological significance. All maps were produced at a scale of 1:7,000,000 cm. Appendix 3, presents the 1,000 year interval sea level depth/age relations used in the final modelling process. Presentation of Late Pleistocene and Early Holocene archaeological sites in their primary context is seen in Appendix 5b and discussed in section 5.1 in terms of spatial location and in sections 5.2 in terms of archaeological significance.

At the height of glaciation (25,000 to 24,000 years cal. BP), the increased land availability within South Australia was to the extent that an additional 200,000 km^2 of area was exposed (Figure 4.8). At this time, the extent of land created was between 20 km and 200 km from the current coastline, the minimum at the very south east of the state, and the maximum in the west. The most observable characteristics evident through these reconstructions are the joining of Kangaroo Island with the current mainland, the continued exposure to the gulf regions, the landform changes occurring along the Great Australia Bight and the Lacepede Shelf, and the continued coastal features of east Kangaroo Island and the Mount Gambier Region. Evident throughout all models is the current South Australian extent, particularly those of the coastal regions in the west, as juxtaposition to the continental shelf. Areas that become integrated into the landscape are those of the Coorong and the lower Yorke Peninsula.

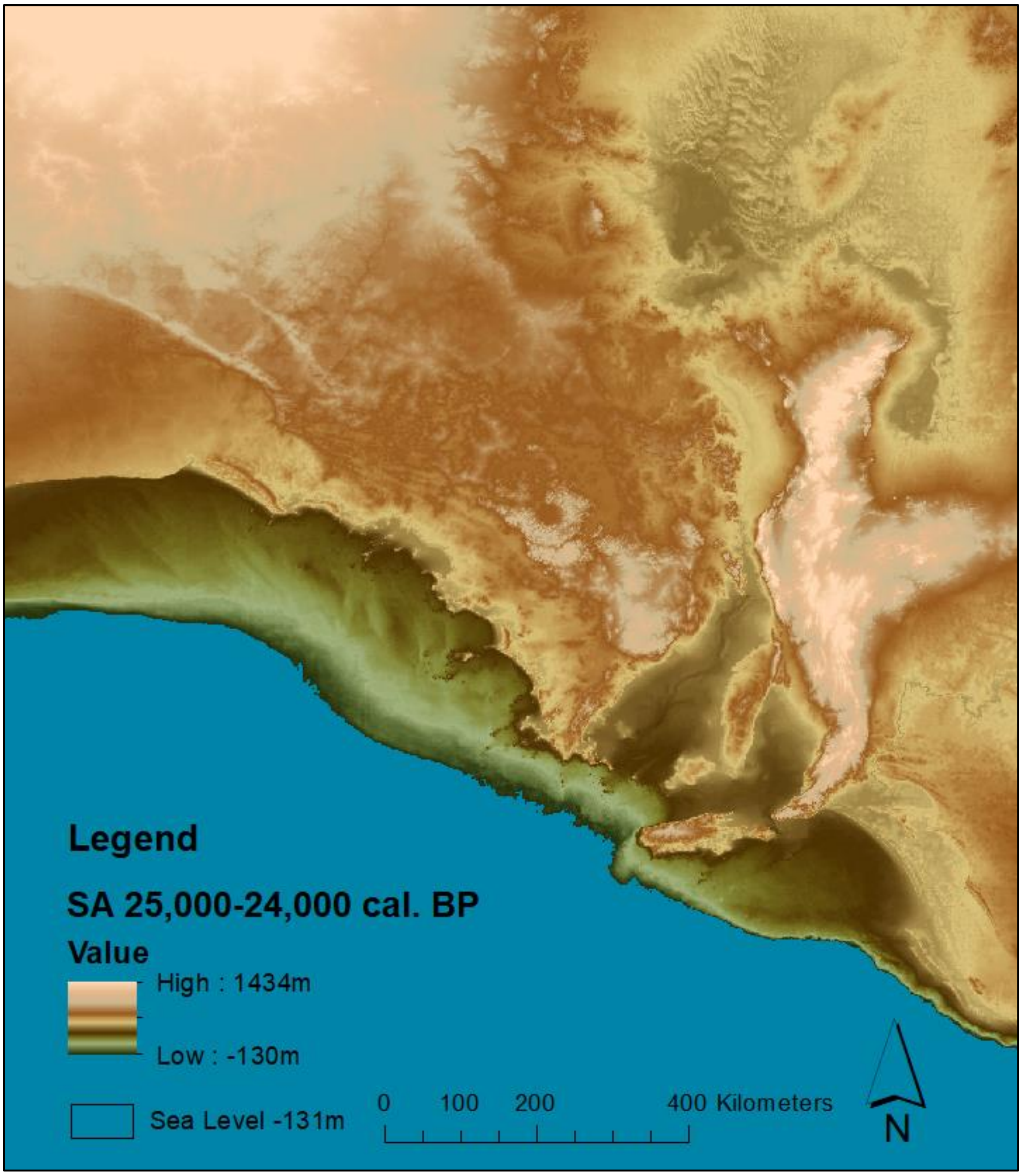


Figure 4.8: Landscape extent and features at 25,000 to 24,000 years cal. BP.

4.2.2 Hydrological Models

The result of the hydrological modelling is presented in Figures 4.9. The model shows the drainage systems of the current terrestrial landscape. These connect to the relict and potential drainage systems of the submerged continental shelf. No other models of this drainage are known for this area, except for those of the Lacepede Shelf seen in Figure 4.3 which differ to those presented in these models. All drainage systems flow through to the coast, with those drainage systems on the shelf connecting to those bay and lagoonal/lacustrine environments in the Late Pleistocene as determined in section 4.1.

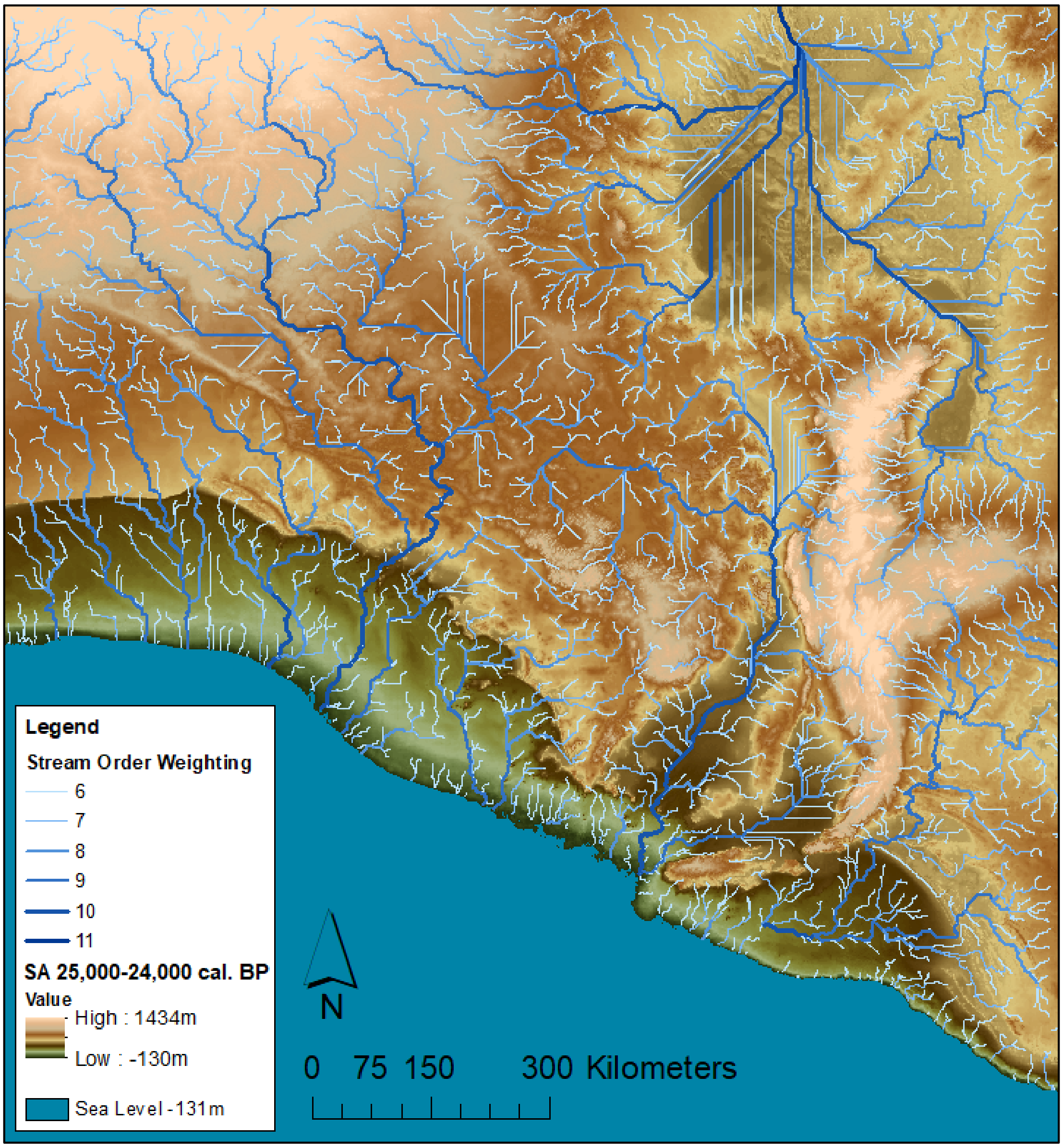


Figure 4.9: South Australia hydrological modelling.

4.2.3 Topography Models

The TPI modelling results of the submerged continental shelf of South Australia are presented in Figures 4.10 to 4.12. They show the relatively flat to gentle sloping of the shelf. The most notable features are the enhancement of the drainage systems in the Spencer Gulf, the steep cliff areas of western Kangaroo Island, the predominately flat topography of the Bonney Shelf, the ridge systems across the Great Australian Bight, and the valley bases between Kangaroo Island and the southern end of the Fleurieu Peninsula. Some of the marine features identified in Geoscience Australia's geomorphological feature class dataset, presented in Figure 4.13, are also noticeable (Heap et al. 2006; Heap and Harris 2008). Specifically, those bank/shoal area features, the terrace features on the Great Australian Bight and Lacepede Shelf, and the escarpments of the Bonney Shelf. These identified topographic features, together with the results of section 4.1 are analysed in terms of their relation to sea-level changes in section 5.1.

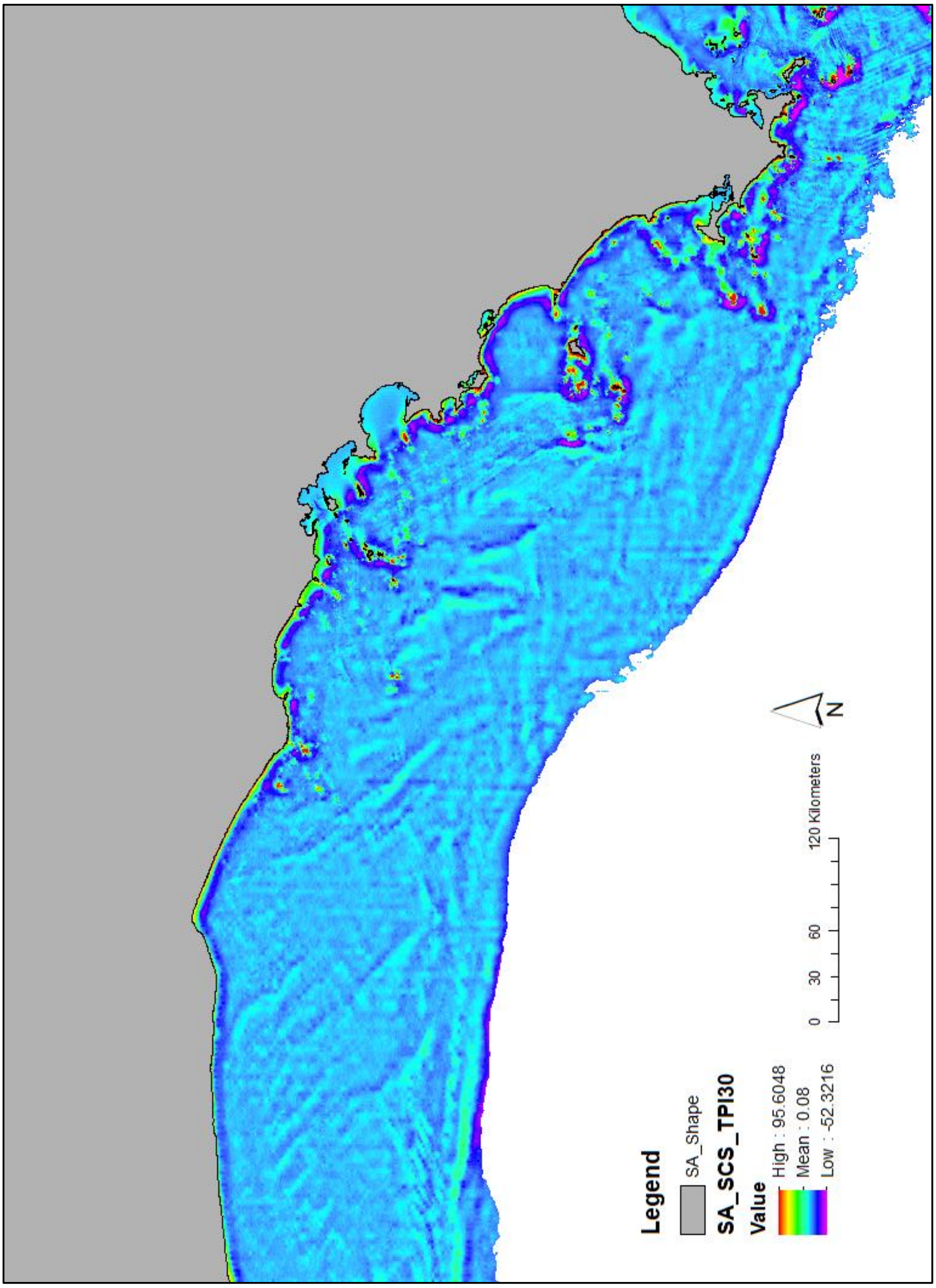


Figure 4.10: South Australia West TPI model.

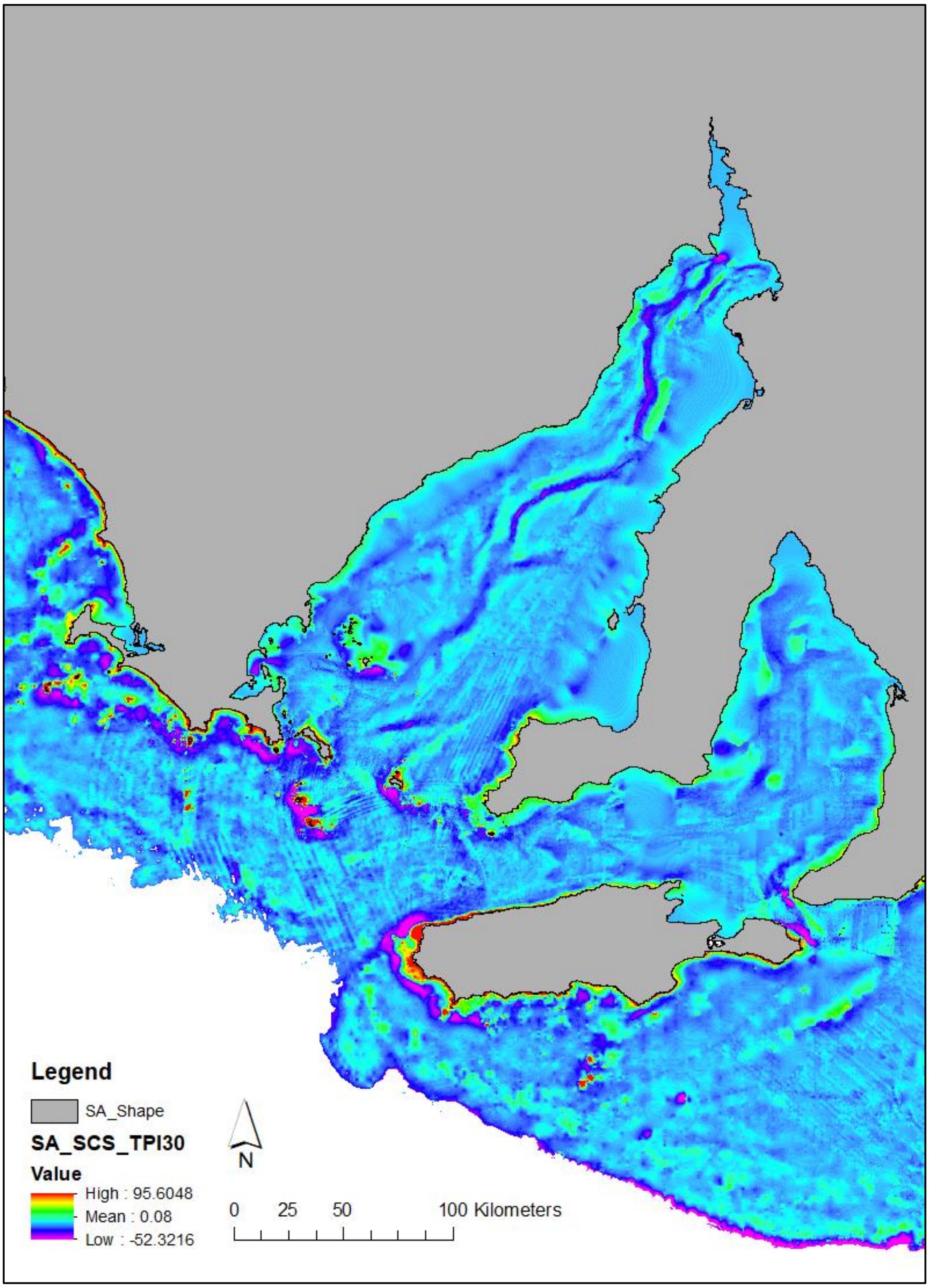


Figure 4.11: South Australia Central TPI model.

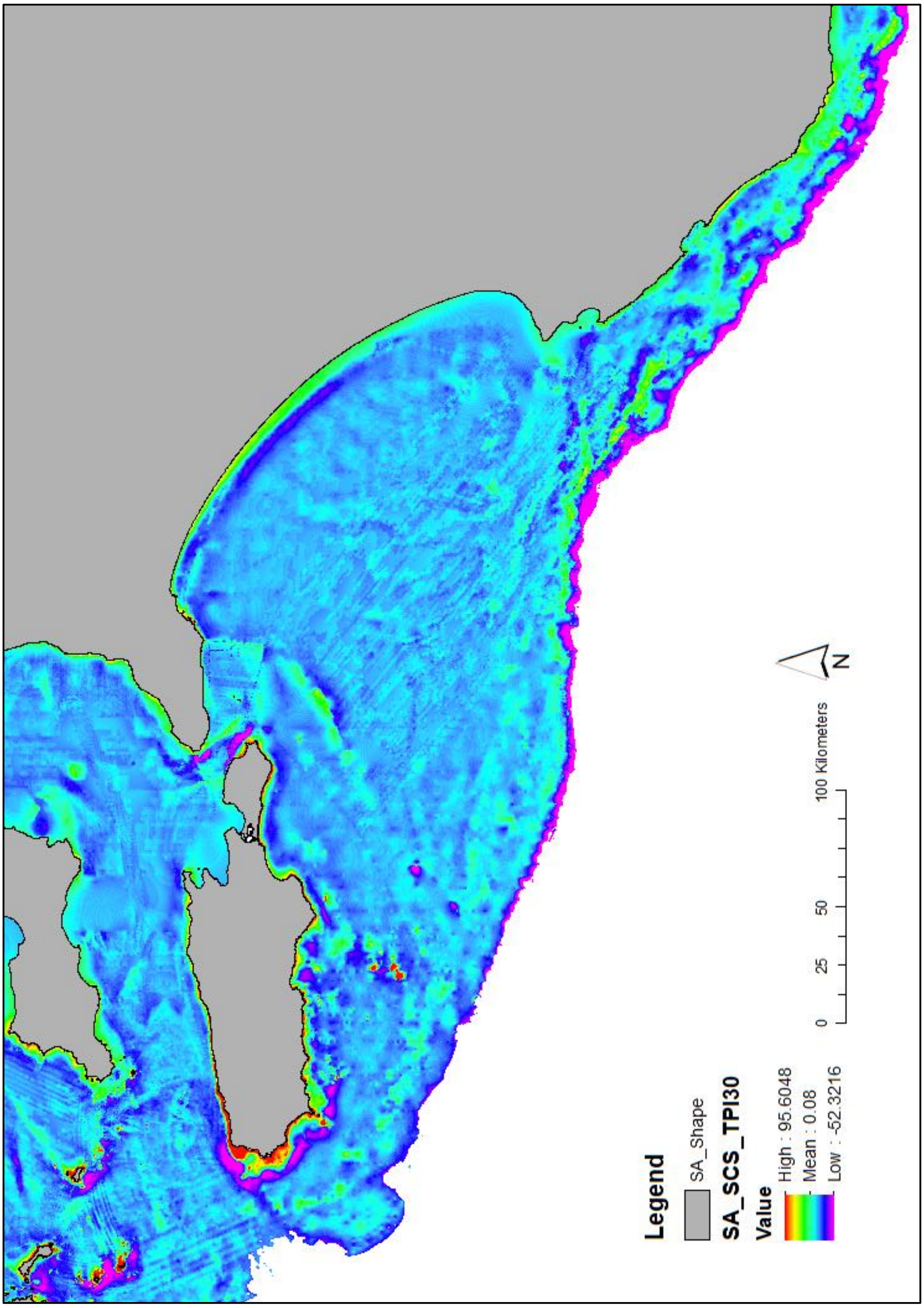


Figure 4.12: South Australia South East TPI model.

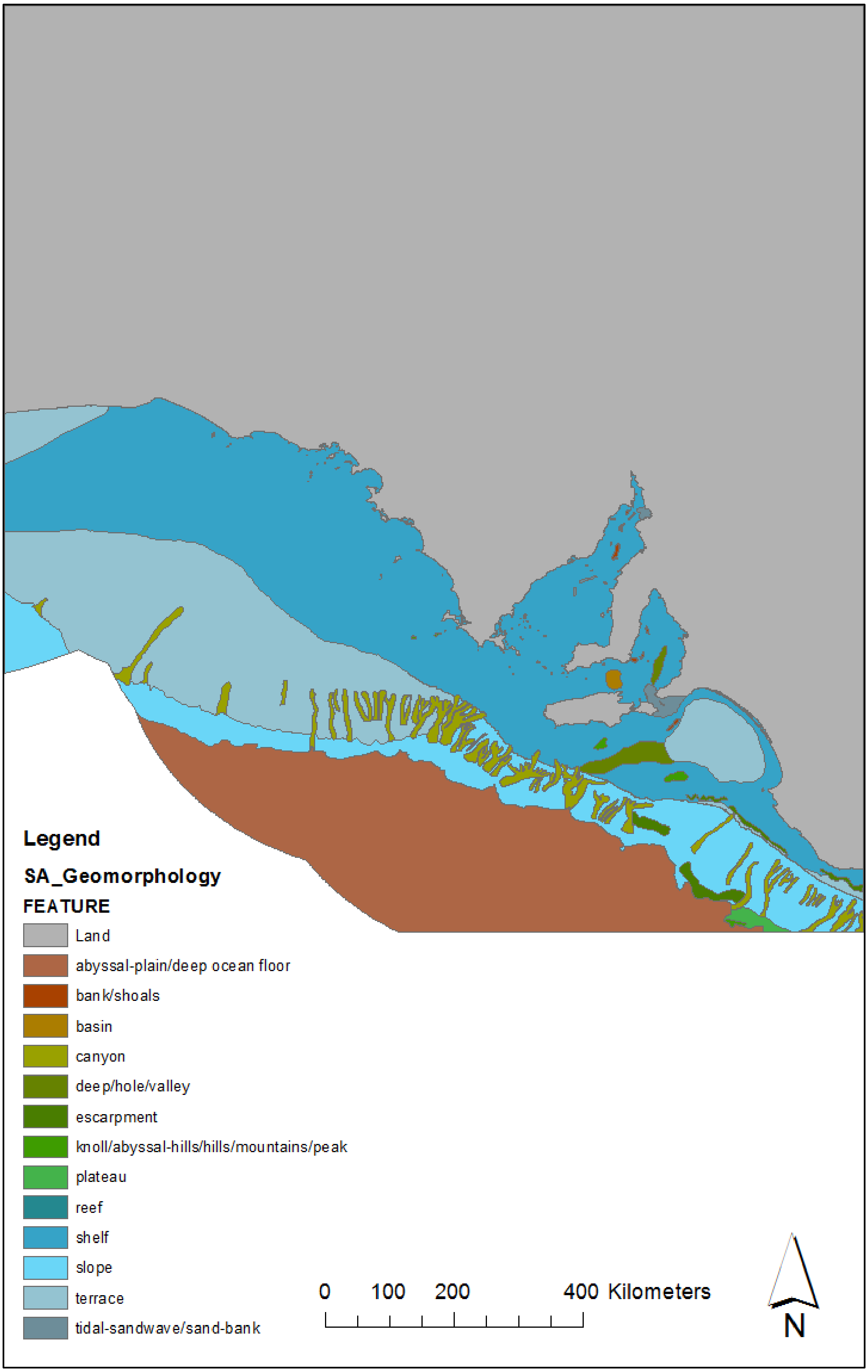


Figure 4.13: Geomorphological features of South Australia (Heap et al. 2006; Heap and Harris 2008).

4.3 Summary

This chapter presented the results of the desktop survey and the landscape modelling for South Australian topographic changes caused by geomorphic processes. These results are complementary to each other and provided information concerning changes throughout the past 50,000 years. These results are discussed further within the following chapter as a narrative, circumstantial context for South Australia and in relation to the significance of such contexts for archaeological purposes.

Chapter 5: Discussion

This chapter presents the analysis and interpretation of the results presented in this study (Chapter 4). The desktop survey, as well as the landscape modelling, are examined in order to produce an understanding of topographic changes for South Australia within the last 50,000 years. This account, together with the review presented in section 2.3, allowed for the exploration of significance of this submerged landscape in South Australia in regard to the discourse within Indigenous archaeology in Australia. Discussions centre on the significance of what has currently been established in this study as well as the hypothetical significance of further investigations.

5.1 South Australian Topographic Context

The combined desktop survey and landscape modelling results presented within this study offer of a broad view of topographic characteristics and changes of South Australia over the last 50,000 years; with a focus on understanding changes to the submerged continental shelf. This was done in order to evaluate space in relation to investigations of the human past. Within South Australian geological history, the last 50,000 years is relatively mild in terms of topographic changes; these changes are visually displayed in Appendix 5a. There are four main periods of change as highlighted in Figure 5.1 in the order of a mild regression period, a period of relative stabilisation, a rapid transgression period, and a subsequent period of stabilisation. At the commencement of the time period, topography is evidently varied compared to the present. Terrestrially, the gulf regions were exposed, the coastal region of the Coorong extended further south, and those coastal areas of the southeast and west began to protrude out from the current extent.

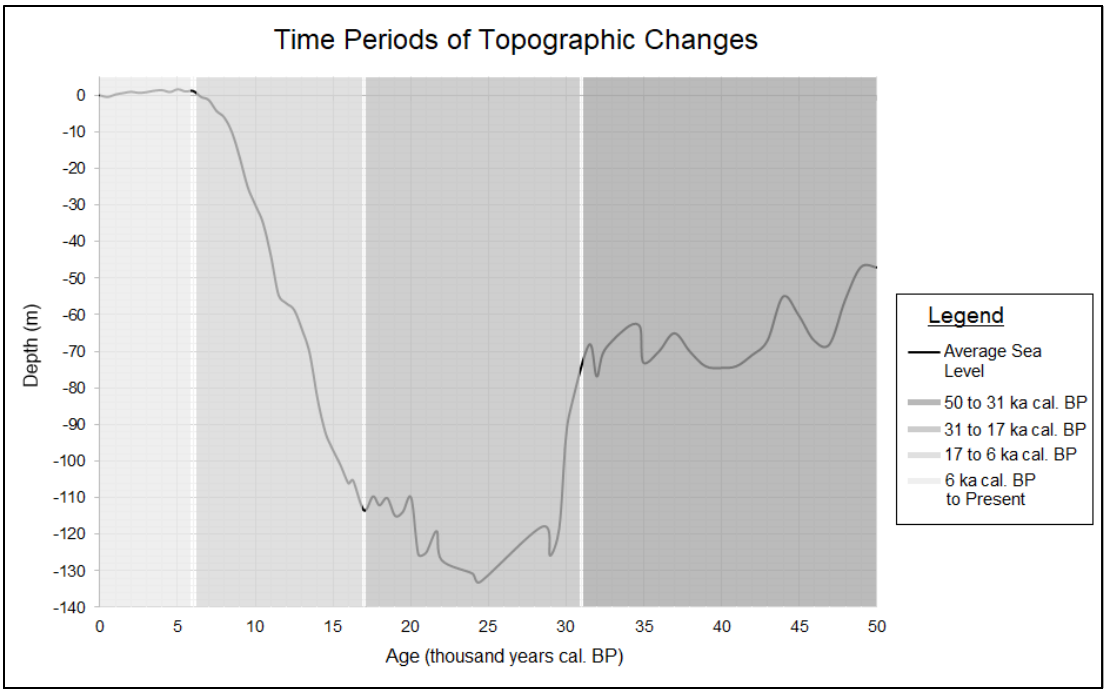


Figure 5.1: Sea-level curve for South Australia, annotated to display time periods of topographic changes discussed in text.

5.1.1 Sea-Level Regression (50,000 to 31,000 years cal. BP)

The period between 50,000 to 31,000 years cal. BP is characterised by fluctuating periods of regressions and transgressions. The first major change to the shelf appeared between 49,000- and 47,000-years cal. BP, which saw the first of the regression periods. There were rapid extensions of the coastal regions, particularly on the Lacepede Shelf, Lincoln Shelf, and Great Australia Bight. The topography in the west was characterised by the transition from smaller to larger cove and island areas. Sea levels stabilised for around one thousand years, before transgressing the region up until 44,000 years cal. BP. Those previously formed topographical features established in the first period of regression were consequently submerged. This process of regression/transgression exchange continued through to 31,000 years cal. BP, with both regression and transgression periods lasting between one thousand to four thousand years. The regressions would have created not only new terrestrial landforms, but continued reworking of lagoonal systems on the Lincoln Shelf. This period would have also seen constant movement of the ancient Murray River Mouth, moving progressively southwest below the hill landform of present Kangaroo Island. At the end of this period (31,000 years cal. BP) as much as 10 m of sea level was lost in a one-thousand-year period. In this time, islands and peninsulas became less prominent, with the formation of large, continuous terrestrial plains.

Features that were consistent throughout this period and into the next were the continued exposure of the gulf regions and present-day Backstairs Passage. The Spencer Gulf would have been a gentle sloping flood plain with a stream channel running through its centre, opening into a stagnant lacustrine basin to the south. Gulf St Vincent would have become an open central drainage depression/basin complex. The surrounding topography would have fed drainage into this basin, with potential outputs from the current Karrawirra Parri (River Torrens), Field River, and Onkaparinga River located in the Adelaide Plains region. Backstairs Passage would have been a steep gorge/valley area, with no drainage. However, intermittent accumulation of water may have been prevalent in the gorge areas. The Indigenous presence in South Australia recorded for this period is represented by Allen’s Cave and Warratyi. Allen’s Cave, dated to 40,000 years cal. BP, was located ~150 km from the coast compared to 17 km at present (Figure 5b.2). The inland site of Warratyi, dated to between 48,000 years cal. BP and 33,000 years cal. BP, was located between 590km and 560km from the contemporaneous coastline, compared with its present location ~240 km northeast of the top of the Spencer Gulf.

5.1.2 Sea-Level Stabilisation (31,000 to 17,000 years cal. BP, LGM)

Only slight topographic changes occur between 31,000 and 17,000 years cal. BP, with minute regression and transgression of sea level. The most change seen is between 30,000 and 29,000 years cal. BP, when sea levels drop ~30 m. From then, movement of sea level occurs within a 20 m vertical range, with the lowest sea level achieved at the start of the LGM at 25,000 to 24,000 years cal. BP, down to –131 m. Though the range of movement is large, its impact is small, due to the nature of the submerged continental shelf; the topography increases in steepness towards lower depths. For the Great Australian Bight region, the area becomes a terrestrial plain littered with gentle sloping ridges edging towards an escarpment coastline. These ridge patterns dictate both the major and minor drainage systems within the region. The extent of watercourse permanency is unknown, so too is the extent of karstic cave systems and underground water systems. The escarpment coastline reaches to the edge to the south east of the state. The Indigenous presence in South Australia recorded for this period are that of Koonalda Cave, Roonka Flat, Hawker Lagoon, JSN Site, NE Madigan Gulf, and Warratyi. At Koonalda Cave, dated to between 26,000 and 19,000 years cal. BP, the coastline would have been a consistent ~190 km from the site, compared to 23 km at present. At Roonka Flat, (dated to 22,000 years cal. BP) the site would have been ~340 km away from the mouth of the Murray River, as compared to 150 km at present.

The isolation of the northern archaeological sites from the coastline becomes more apparent during this period. Warratyi, dated to between 30,000 and 25,000 years cal. BP, sees approximately 40km added to the distance exhibited between 48,000 years cal. BP and 33,000 years cal. BP. Hawker Lagoon, dated to 18,000 years cal. BP, would have been located ~500km inland compared to ~120km from the top of the Spencer Gulf at present. JSN Site, dated to 18,000 years cal. BP, would have been located ~880km inland compared to ~490km from the top of the Spencer Gulf at present. NE Madigan Gulf, dated to 22,000 years cal. BP, would have been comparable to that of the JSN site at ~750 km inland, compared to 410 km from the top of the Spencer Gulf at present.

5.1.3 Sea-Level Transgression (17,000 and 6,000 years cal. BP)

Between 17,000 and 6,000 years cal. BP, sea levels begin to transgress the landscape at a steady rate, to which loss of terrestrial land was extensive. Transitioning from 16,000 to 15,000 years cal. BP, the former coastline and terrestrial areas present during sea-level stabilisation begin to vanish. Islands and peninsulas reform then disappear through 15,000 to 11,000 years cal. BP. Most notable is the rapid inundation between 14,000 to 13,000 years cal. BP, with an increase in almost 20 m of sea level. The period between 11,000 to 10,000 years cal. BP sees the greatest physical changes, resulting in the inundation of most of the coast to just below present levels and the inundation of the gulf regions. This period also sees the rapid drowning of Backstairs Passage begin, with inundation beginning at 9,000 years cal. BP. Complete inundation of the continental shelf occurs by 6,000 years cal. BP. Indigenous presence is greatest during this period of transgression, in terms of the dated Late Pleistocene and Early Holocene archaeological record. Sites include Allen's Cave, Balcoracana Creek, Bevilaqua, Cape du Couedic, Cape Martin, JSN Site, Koonalda Cave, Koongine Cave, Mt Burr, Roonka Flat Dune, Seton Rockshelter, White Crossing, and Wyrie Swamp.

After the recorded material presence at Allen's Cave at 40,000 years cal. BP, material deposits are not recorded (dated) until 14,000 years cal. BP. At this time, Allen's Cave was still comparatively inland at ~160 km away from the coastline. Only around

11,000 to 10,000 years cal. BP does the distance between Allen's Cave and the coastline decrease to almost present-day conditions. Unlike Allen's Cave, Koonalda Cave exhibits continued stability in its spatial location (at 190km from coastline) for its recorded date of 17,000 years cal. BP for this transgressional period.

For Seton Rockshelter, dated to 16,000 years cal. BP, the distance to the contemporaneous coastline would have been ~60 km compared to 12 km at present. Furthermore, at dated periods of 13,000 to 11,000 years cal. BP, Seton Rockshelter was closer to the coastline at 20 km. For Cape du Couedic dated to 8,000 years cal. BP there is no change in distance away from coastline (500 m).

For those sites located in the northeast of South Australia, distances between the contemporaneous coastline and the present coastline remains consistent to those dated to the prior regression and stabilisation periods. Balcoracana Creek, dated to between 16,000 and 10,000 years cal. BP resided at 580km and 420km from the coastline, compared to 230km at present (to top of Spencer Gulf). JSN Site, dated to between 17,000, and 12,000 years cal. BP resided at 850km and 800km, compared to 480km at present (to top of Spencer Gulf). White Crossing, dated to 14,000 years cal. BP, resided at 770km from the coastline, compared to 460km at present (to top of Spencer Gulf).

Of those sites in the southeast of the state (Bevilaqua, Cape Martin, Koongine Cave, Mt Burr, Roonka Dune Flat, and Wyrie Swamp), dated to between 12,000 and 7,000 years cal. BP, a distinct movement in sea level is observed, causing the coastline to encroach on the sites, potentially within generational memory of the people using those sites (Figures 5b.19 to 5b.24). Between 12,000 and 10,000 years cal. BP, sites of Cape Martin, Koongine Cave, and Wyrie Swamp were located between 5 to 20km in distance from the coastline, with Mt Burr occurring at a slightly greater distance of 25km from the coast. These distances decrease as sea level continues to rise between

9,000 to 7,000 year cal. BP, with the distance to coastline being comparable to the present coastline (minimal [<5m] to no distance).

5.1.4 Sea-Level Stabilisation (6,000 years cal. BP to present)

From 6,000 years cal. BP to present, sea levels rise 1–2 m above present level before stabilising. The coastline varies very little to that of the present. The only notable difference is the flooding of low-lying areas such as the Adelaide Plains region, the lower southeast, the Coorong, and the northern most section of the Spencer Gulf.

5.2 Archaeological Significance

The evaluation of significance is utilised within this study as a process of determining the contribution of continued archaeological investigation of the submerged continental shelf to the current study of the human past. Significance assessment is conducted using the guidelines set by *Australia ICOMOS Burra Charter, 2013* on cultural significance; as a guideline for Australian best practice from heritage protection. The submerged continental shelf is considered here as a place of cultural significance with the potential need for cultural heritage management of the area, irrelevant of archaeological identification. Though the *Burra Charter* caters to the identification of cultural significance, its use in archaeology in Australia is wide spread in application. Hence the borrowing of procedure, where the first step within the charter commands the process of determining significance by understanding a place and assessing its cultural significance (ICOMOS 2013a:10).

Significance here is evaluated under scientific value within the *Burra Charter* (ICOMOS 2013b:2–4). To evaluate scientific value, the ICOMOS (2013b:3–4) Practice Note for Understanding and Assessing Cultural Significance was used where this assessment is concerned with the information surrounding a place's nature, and a place's ability to reveal new or further information pertaining to its past, through examination or investigation (can be archaeological). As specified by ICOMOS (2013b:3), 'the relative scientific value of a place is likely to depend on the importance of the information or data involved, on its rarity, quality or representativeness, and its potential to contribute further important information about the place itself or a type or class of place or to address important research questions'. The question to pose for such an assessment of scientific value is: 'would further investigation of the place have the potential to reveal substantial new information and new understandings about people, places, processes or practices which are not available from other sources?' (ICOMOS 2013b:4). It could be argued that the short answer is yes. However, the question and its answer do no more than to stipulate an impression of significance rather than develop an understanding of the implications of its significance in terms of continued study. Therefore, the question posed for significance here is rather: how would further investigation of the place add to the knowledge already obtained and understandings developed about people, places, processes or practices which are not available from other sources? This question requires demonstration of the types of knowledge and understandings that may be acquired and feeds back into the second question asked in this study. The significance investigation here is of two types; the significance of the present research, and the significance of future investigations. The former focuses on the implications of the *why* factor of the integration of context and continued investigation. The latter is of a hypothetical nature and endeavours to elaborate on the *what* factors of investigation (e.g. what is missing). In the latter case, hypothetical potential requires further investigation to ascertain positivity.

For this discussion, significance assessment is divided here into those which focus on cultural materials/sites and models. Cultural material/sites concerns the identification and investigation of material locations and refuse; focusing on addressing the type of information that could be obtained. On the other hand, archaeological models are those theories used to explain human activity throughout the past. Here, this explicitly refers to understanding human movement and activity such as colonisation and occupation/settlement. In the broadest sense, significance here concerns contextual implications to understanding cultural changes (if any, their causes and results), landscape/human interactions (environmental changes), material use and distribution, nodal site interactions (systems vs individuals), exchange (information or material), site localities (situational), and differences or similarities in other cultural practices (static or fluid change across space and time) (see Reitz and Shackley 2012:469–482). Further to this, significance lies in the integration of Indigenous archaeological practices with those of submerged landscape practices.

5.2.1 Cultural Material/Sites

The investigation of the circumstantial context of South Australia, to the study of cultural material/sites, is significant for two main reasons. The first concerns the implications of interpretations of sites in their past context rather than their current context. The second concerns the hypothetical distribution and preservation of sites on the submerged shelf. As demonstrated in section 5.1 and Appendix 5, major topographic changes have occurred in South Australia throughout the past. By understanding these changes in relation to present site localities, an increase in accuracy of regional context can be attained. This is particularly focused on the nature of Late Pleistocene and Early Holocene coastal sites. As examples of significance those sites of Allen's Cave, Koonalda Cave, Seton Rockshelter, Cape du Couedic, Wyrie Swamp, and the collective northeast will be discussed.

For Allen's Cave and Koonalda Cave, investigations of past context concerns understanding site placement and occupation in relation to topographic changes. As highlighted in section 5.1, Allen's Cave and Koonalda Cave sites would have been confined within an inland context. Within the context presented in Appendix 5a, any regression or transgression of sea level is interpreted to have minimal impact to site use, with occupation occurring at times of various sea levels. Site and material use are then interpreted to be dependent on the requirements of the people using the sites. As alluded to in section 2.3.2, the potential exists of the exchange or development of socio-cultural behaviours with people who may have been present on the exposed topography of the Great Australia Bight. This extends to the potential exchange of marine resources with coastal regions. Any interpretation of extra-site relationships should therefore be considered in its past context. Of interest is Cane's (2001:144) interpretations which correspond with understanding landscape changes for archaeological purposes:

> It seems feasible that the openness of the social and natural environment of the Nullarbor Plain during the Late Pleistocene would have accommodated either a migratory coastal people or the development of a system of trade and exchange in a manner that was not catastrophic, but which would nevertheless have necessitated some modification to the customs and traditions of the current residents as competition for resources (both social and economic) increased.

Any future archaeological investigation of the submerged continental shelf could improve present understanding of the human past.

For the Seton Rockshelter and Cape du Couedic, investigation of past context concerns their relationships to the surrounding topography: understanding spatial distribution and landscape occupancy. From a spatial perspective, both sites are comparatively different. In the case of the Seton Rockshelter, when occupied at 16,000 years cal. BP, present day Kangaroo Island was connected to both the Fleurieu Peninsula and surrounding shelf areas, with the island a hill/plateau landform. For Cape du Couedic, occupied at 8,000 years cal. BP, there is no apparent differences between the current coastline and that of the past. Use of the site occurred approximately 2000 years after inundation of Backstairs Passage, forming the present extent of Kangaroo Island.

For sites in the southeast region such as Wyrie Swamp, context concerns the spatial distribution of sites and understanding responses to topographic change. As stated in section 5.1.3, those sites around and including Wyrie Swamp, saw distinct movement of the coastline during occupancy. These sites are used in an area that, for the period, was always coastal. The sites demonstrate a gap within temporal distribution, with no Late Pleistocene sites present older than 12,000 years cal. BP. It is unknown as to the extent to which these sites indicate responses to environmental changes, because these older sites do not exist or have not yet been identified. Sites such as JSN, Balcoracana Creek, Hawker Lagoon, and Warratyi have relatively minimal contextual impact from this study beyond refinement of context. The circumstantial context, however, is significant in terms of models of occupation as discussed in section 5.2.2.

Overall, there is a gap in the spatial and temporal location of sites dated in South Australia to the Late Pleistocene, to the extent that between 50,000 and 13,000 years cal. BP, there is no recorded presence of coastal sites in South Australia. Moreover, throughout this period, sites are restricted to the far west and far east of the state. Of those sites dates to the Late Pleistocene, sites in the current coastal setting are predominantly in areas that were once higher ground, and are still primarily higher ground at present. Allen’s Cave, Koonalda Cave and Seton Rockshelter as situated on escarpment/cliff landforms. Site features of the inland regions are predominately consistent with this observation whereby: 1) Roonka Flat can be viewed as an extension of this observation, where it is located in higher ground away from the river system; and 2) those sites inland are either in low-lying areas close to flood plains or in higher areas of mountainous regions (Balcoracana Creek, NE Madigan Gulf, JSN Site and White Crossing, vs Hawker Lagoon and Warratyi, respectively). Coastal Late Pleistocene sites may have been located in open low-lying areas, however evidence for this is slim. This is attributed to the nature of topographic changes rather than cultural decisions where coastal sites may no longer be present due to weathering and erosion caused by geomorphological processes, and their subsequent submersion. Early Holocene sites in current coastal settings are predominantly in lower-lying regions, with the exceptions of Allen’s Cave and Koonalda Cave in the west where these are seen to be associated with prior site use in the Late Pleistocene.

For the hypothetical, the significance lies in the finding of material underwater, on shelf areas. Any identification of sites or materials, will add knowledge, whether the additions coincide with current knowledge, supersedes or disputes that knowledge, or adds new knowledge that is not known in the archaeological record about past human activity. Furthermore, any knowledge will be significant in understanding the spatio-temporal distribution of humans in the past. Highlights of hypothetical scenarios include the preservation of both inorganic and organic materials. Those inorganic sites and materials include stone artefact scatters and isolated finds, fish traps, quarry locations, humanly modified landforms and engraving sites (Dortch 2002; Smith and Burke 2007:165–169). Those organic sites and materials include shell middens, scarred trees, ochre rock art sites, and burials (Smith and Burke 2007:165–169). Of the inorganic, identification of potentially rich resource areas for stone tool production could be used as an identifier of the expanse of stone tool industries within Late Pleistocene South Australia. Stone artefact identification would aid in the understanding of distribution and evolution of tools and materials; further to the identification of exchange of human activities and behaviours.

Of the organic, the main significance would be the identification of shell middens. The identification of these materials would be significant in terms of the distribution and evidence of use in Late Pleistocene coastal and lacustrine environments, and potentially as a relative indicator of past sea level for South Australia. Although a Holocene phenomenon in South Australia, the identification of tree and wood remains, such as scarred trees and boomerangs, could demonstrate material use in the Late Pleistocene, or at the very least the identification of floral distribution; as seen with Wyrie Swamp (Luebbers 1975:39). In addition, there remains a potential for the preservation of watercraft, as a Late Pleistocene material product. Identification of these would contribute to the extent of object construction and use. The significance of rock art discovery would contribute to understanding the spatio-temporal distribution of style types, and cultural exchanges. Burials would also work on a similar basis in terms of understanding the spatio-temporal distribution of burial practices. However, any identification of burial remains, or any materials of an Indigenous nature, would be accountable to the state and federal laws protecting these materials. Where sites are known only to be attributed to the Mid to Late Holocene such as earth mounds, an openness to the identification of such sites would be significant in terms of site type distribution spatially and temporally. For earth mounds, with locations along the Murray River and the Fleurieu Peninsula, investigations in adjacent locations of the Spencer Gulf and the Lacepede Shelf may be fruitful (Westell and Wood 2014:31-32).

In terms of evidence of economic and social activities, these will be present in the archaeological record. Specifically, as it relates to the shelf, the understanding of economic and social activity of coastal life ways in the Late Pleistocene may be present in inorganic and organic material remains (Hall and McNiven 1999:3). Also, identification of material would enable analysis between Holocene coastal adaptations and Late Pleistocene coastal adaptations, and as a means to support or undermine intensification and deterministic arguments (Hall and McNiven 1999:3). As emphasised by Hall and McNiven (1999:4):

> An unfortunate trend is emerging where regional overviews of subsistence patterns are being inferred from only a handful of sites. In some situations, information is available on long-term marine resource use at a few sites but almost no information is available on regional settlement patterns, mobility patterns and the like. As a result, little detail is available concerning the representativeness of excavated sites or how they relate to other sites in the region.

Investigation into the submerged continental shelf as a component of primary context would help aid regional studies. At present, the majority of all current marine orientated coastal sites will, apart from those sites dated to the Late Pleistocene, be related to current sea level and therefore Holocene activities.

5.2.2 Models

Models have been used within archaeology for a variety of reasons, from depicting spatio-temporal technological distributions to depicting changes in population distribution. Within the archaeological study of the Late Pleistocene, models moved from depicting variability and change, to predicting the past (Allen 1993:139). Those current models of prediction are inherently minimalistic, and are concerned with features of shortest distances and lowest sea levels (Allen 1993:140). As Allen (1993:140) highlights:

> As a *strategy*, developing minimalist hypotheses when there are few or no data is a logical procedure because they demand the fewest assumptions. However, they require continued testing and revision. The danger with this approach is precisely that the superficial support which fragmentary data bring to such minimalist hypotheses will not be further questioned; indeed, this support often obscures the need to seek alternative explanations.

This is true in the case of models used to depict past human activity in Australia. Models depicting evidence of human activity are predominately presented irrespective of temporal site distribution and within a predominately secondary (the present) or LGM contextual landscape, with interpretations based on these contexts (see Smith et al. 1993 and Smith 2013:73,111). Therefore, the significance of circumstantial context investigations serves to test previous models and hypotheses in terms of spatio-temporal settings of archaeological sites.

Within Australia, the most common minimalist models are those which present arguments for the initial colonisation of Sahul and the resultant occupation of that landscape. The debates over the process of colonisation fall within three distinct arguments (O’Connell and Allen 2004:835). Those models propose colonisation via inland routes, coastal routes, and routes based on water availability (Figure 5.1). The model for an inland route was first presented by Joseph Birdsell in 1977. The model sees theoretically traditionally maritime orientated modern humans arrive in Sahul and adapt to a terrestrial, land-based economy (Birdsell 1977:113–114, 147–148). Through this adaption, modern humans would have needed to expand across the land surface as the population increased (Figure 5.1a) (Birdsell 1977:148).

The second colonisation model proposed by Sandra Bowdler (1977:205), concerns the colonisation of Sahul via a coastal route (Figure 5.1b). Bowdler (1977:205,233) theorised that the people who colonised Australia were adapted to a coastal lifeway and that they continued this lifeway on their arrival and habitation of Sahul. After colonising the exterior of Sahul, people would have moved towards the interior via major river systems (Bowdler 1977:205). In 1990, Bowdler re-examined her theory to take into count the growing number of Pleistocene Indigenous sites being discovered in Australia's interior (Bowdler 1990). In her re-examination, Bowdler (1990:337; 1992:569) still theorised a coastal colonisation route, however, considers a more rapid adaptation to new environments by Indigenous peoples, such as deserts.

The third colonisation model, proposed by David Horton (1981:24), concerns the possibility that the colonisation of Sahul was driven by the availability of fresh water (Figure 5.1c). Horton (1981:24) demonstrated this as a relationship between the amount of fresh water available and the range of mobility with which Indigenous peoples could travel; with a restriction placed on available water sources, Indigenous peoples would opt for a sedentary lifestyle. Horton (1981:23) also supposed that those who colonised Sahul had neither entirely coastal nor inland economies. He suggests that their economy system was all-purpose which could be applied to any environment by simply changing the main food staples (Horton 1981:23).

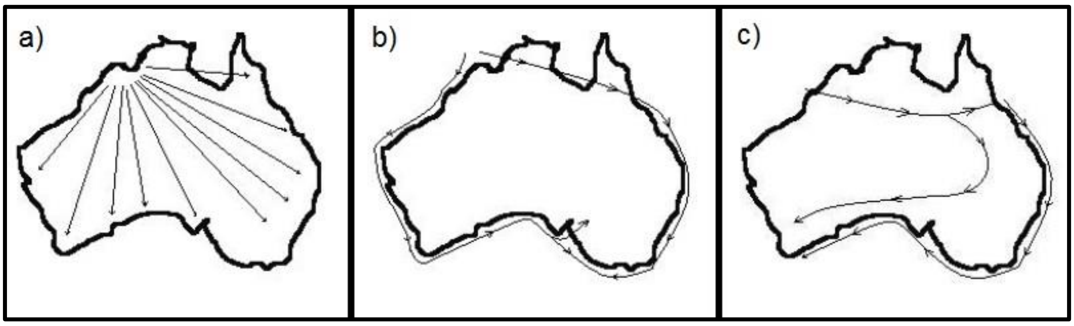


Figure 5.1: Colonisation theories depicted as models (After Horton 1981:25).

Of those three arguments, only Horton’s 1981 model is tested by continued research. Conducted by Bird et al. (2016:11478–11480), their research suggests, based on tested least-cost models of recorded occupation site locations, that Indigenous people did not venture more than 20 km from water sources; though they did later after occupation was established (<30,000 years BP). What this theory does not address is Horton’s proposition that, in order to move throughout Sahul, Indigenous people would have had, or required, an adjustable economy.

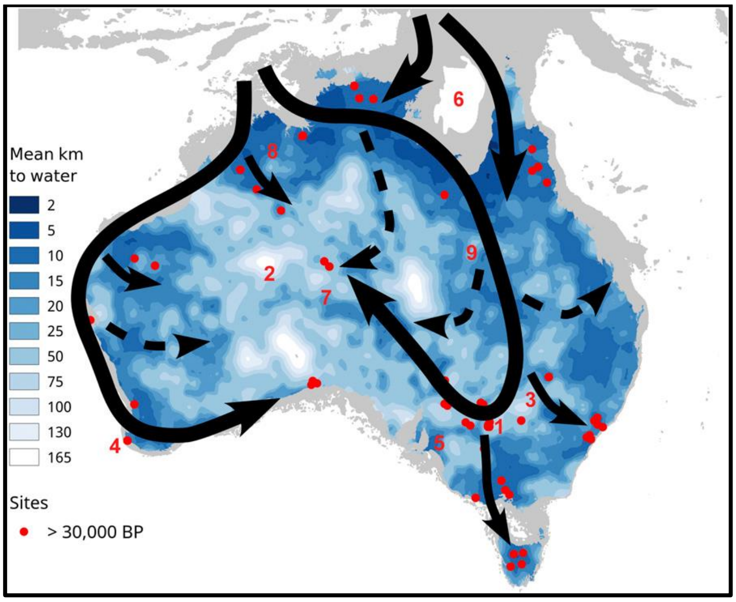


Figure 5.2: Model of colonisation route presented by Bird et al. (2016:11480).

Although these models have merit, there is one issue which these theories do not address: that is the spatio-temporal context of both the archaeological sites and their circumstantial contexts. The past environment was not static but rather fluid in relation to human dispersal. Human movement would not have necessarily been constrained to the current landscape extent, and any models should not only be fluid in depiction of archaeological sites but in the depiction of environment. However, as stated previously, any context on this scale will be inherently generalised, which these colonisation models currently present. For Bowdler's coastal model, serious consideration of the past coastline needs to take place. For Horton and Bird et al. consideration of water sources, investigation should also involve the inclusion of those water sources that would have been present on the continental shelf. Those gaps in water sources in the landscape presented in Figure 5.2 are prevalent in the South Australian region. As a karstic landscape with the terminating Murray River, the South Australian continental shelf would have contained river systems, lakes, springs, and potentially water filled cave systems.

These colonisation models and subsequent occupation models further manifest into the archaeological research concerned with absence of evidence. Absence is presented as an argument in which an absence of material evidence in an area has meaning (Owen 2015:75). In the case for the circumstantial context of South Australia, absence can be argued to have no meaning unless proven otherwise: absence as a justification for not investigating a geographical area (Owen 2015:75). Regarding the lack of archaeological evidence in South Australia, it can be argued that a lack of human occupation cannot be determined unless adequate evidence, other than an absence of archaeological evidence, is recorded (e.g. the support of environmental evidence). If we cannot understand the nature of the past landscape, or choose not to acknowledge it, then any interpretations at regional areas will fall short of demonstrating an understanding of Indigenous occupation of South Australia, and the larger Australian continent. Absence does not mean a lack of presence. It means that any material evidence relating to a presence does not exist. Research into the submerged continental shelf will provide greater evidence for either argument depending on the identification of cultural material. The most notable example of this is Cane's (2001:153) comment on the state of maritime economic activity in Australia, where arguments are made of its perceived dominance in the temperate south-eastern region of Australia compared as unimportant in the arid southwestern region of Australia. South Australia offers the possibility to investigate this comment where the state's submerged continental shelf may demonstrate both environment types, along with the preservation of material to add to the argument. It is not that maritime activity was unimportant in arid south-west Australia, but rather, there is no archaeological evidence from time periods of lowered sea level to support changes in landscape use (if any). If coastal sites were used in the Late Pleistocene in other locations, this would suggest Indigenous peoples movement throughout Australia along some habitable coastal areas, where any evidence of this would be destroyed or submerged.

5.2.3 Future Research

In regards to the topographical changes, archaeological sites and hypothetical scenarios presented in this chapter, recommendations about the direction of future research can be offered. In short, any further archaeological investigation into the submerged continental shelf of South Australia will be rewarding prospects. However, the one key area of interest concerns localised investigations, to further understand context. Those investigations should concern the further development of an understanding of geomorphological process of the submerged continental shelf and topographic changes, coupled with an understanding of the local archaeological record. Investigations can be multidisciplinary and focus on:

- Developing higher quality bathymetry data, to model landscape changes and aid site location investigations;
- Developing detailed understandings of sea-level changes, topographic changes and local micro environments throughout the past (e.g. sediment deposition during multiple transgressive and regression periods, and erosion/scour impacts on modelling);
- Determining groundwater sources and riverine/lacustrine sources on the submerged continental shelf;
- Determining climatic extent across the submerged continental shelf as it relates to human activity.
- Interpreting individual site contexts in relation of the recorded materials at the site and the activities which they represent.
- Dating and calibration of terrestrial archaeological sites believed to be of Late Pleistocene and Early Holocene age, where possible.
- Defining 'coastal' as it relates spatially to the continental shelf throughout the past, and its archaeological implications (e.g. coastal but not marine/maritime related site types).

Eventually, further investigation of this landscape will to lead investigations focused on identifying archaeological deposits on the shelf, interpretation of these deposits and the physical circumstances in which they occurred, and incorporating these into the larger theories and models of Indigenous activity in Sahul. Based on the results of this study, future investigations are encouraged for the gulf regions and the Lacepede Shelf. Both areas have a high potential to contain material remains, particularly in terms of their preservation environments created by marine sedimentation and partial protection from currents (section 4.1). For the gulf regions, investigations should focus on two key locations. The first is the lagoonal/lacustrine environments in the Spencer Gulf. The second is the basin/plain region of Gulf St Vincent. Investigation of both regions would not only gather new information regarding the environment of the past, but could potentially locate new site types not present in South Australia during the Late Pleistocene. For the Lacepede Shelf, investigations should focus around the banks of the Ancient Murray River identified in Figure 4.3. Investigation of this region could potentially, not only gather new sea level records, but also identify the extent and age of Murray River use in South Australia (see section 2.3.3 for overview of Late Pleistocene site Roonka Flat). These directions in research will require localised, large scale investigations into the geomorphology of the areas as context to find cultural material remains.

Two other areas of interest are the Great Australian Bight and the overall investigation of cultural landscapes. In terms of the former, those gaps in knowledge identified by Cane (2001) can be answered through the investigation of the Great Australian Bight region. However, the success of these investigations will depend entirely on the methods they employ, due to the nature of marine processes acting upon the shelf and the potential restricted access to the sea floor, whereby investigations will be depth and weather dependent. In terms of the latter area of research, further investigation should concern the identification of cultural landscapes, and the identification of the cultural process through which this physical landscape is transformed and is therefore attributed a cultural meaning (Daniels and Cosgrove 1988:1; Ford 2011:1; Sauer 1925:41–46; Seymour 2000:193).

Ultimately, investigations should not be based on the sole purpose of locating artefactual material and 'sites', but on the integration of the submerged continental shelf studies with continued terrestrial archaeological investigations and discussions, where they apply. This should not discourage investigation, but rather ensure that investigators understand their goals and biases within broader archaeological investigations. Investigating this landscape requires clear objectives for what archaeologists want to know. These objectives do not have to be the be-all and end-all for research; they can be small objectives. To illustrate this, investigations should not be viewed solely as a means to answer the "big" questions (e.g. colonisation methods and earliest date of presence). When sites are eventually discovered, investigations should begin by focusing on protecting, recording, and analysing the site. Eventually investigations will lead to discussions concerned with what new knowledge is obtained and appropriate heritage management. Only then will appropriateness to answering "big" questions be realised.

5.3 Conclusion

This chapter has discussed the changing topographic context of South Australia and its investigatory significance in Indigenous archaeology. It has incorporated the created circumstantial context with the current archaeological context in order to provide a view of the contributory factor of continued investigations into the submerged continental shelf of South Australia.

Chapter 6: Conclusions

6.1 Summary

This study presented the findings of the investigation into the nature of the topographic changes of South Australia and its significance to the Indigenous archaeological discourse. Specifically, it applied two desktop-based approaches to ascertain the changes occurring over the last 50,000 years, and the appropriateness of these changes to investigations into cultural material and archaeological models. Connections were made to the nature of present archaeological sites and the topographic changes, to distinguish importance and relevance. The first approach, a desktop survey, established a broad history of geomorphic processes influencing these topographic changes. The second approach demonstrated these changes in a visual manner. Together, using those theories and evidence presented in the literature review, a definition of circumstantial context of South Australia was created and its application to archaeological investigations was established. This investigation was conducted in order to progress towards a greater inclusion of environmental considerations within wider Indigenous archaeological discourse, whilst also moving towards continued submerged landscape investigations in South Australia.

6.2 Reconsidering the Question and Aims

This study set out to answer two interrelated research questions: What were the topographical changes that occurred within South Australia over the last 50,000 years? And how does investigating these topographical changes contribute to the discourse of Indigenous archaeology in South Australia? Through the addressing of the aims and objectives, the topographical changes occurring over the last 50,000 years were identified and contextualised in terms of the human presence in South Australia as determined through archaeological investigations. The significance of understanding these changes was explored in terms of continued study of the submerged continental shelf for archaeological purposes.

The geomorphological processes impacting South Australian topography were identified and discussed in relation to sea-level changes for South Australia. Sea level was defined, though used as a generalisation of past sea level actuals until further localised data of sea level pertaining to the Late Pleistocene can be produced. The desktop survey and landscape modelling demonstrated significant topographical changes had occurred on a potentially multigenerational level, with potential for varied coastal environments to exist, as well as varied inland environments. At the beginning of the study period (50,000 years cal. BP), the South Australian landscape shared similarities with the present-day landscape whilst differences were also present; where the Great Australian Bight region represented the former and the gulf regions and Lacepede Shelf represented the latter with terrestrial exposure. The terrestrial exposure of the gulf regions and the Lacepede Shelf continued up until 12,000 years cal. BP

Regression of sea level up until 31,000 years cal. BP saw a dramatic increase in terrestrial area, to the extent that at the height of the LGM, a period of relative landscape stability is experiences with a vastly different landscape than what is at present South Australia. The Great Australian Bight, throughout the regression period, was characterised by small peninsulas and islands formed at various sea-level depths. This landscape became a terrestrial plain with gentle sloping ridges throughout the stabilisation period. The terrestrial exposure of the Spencer Gulf and Gulf St Vincent was characterised by two varying landforms. The Spencer Gulf would have been a gentle sloping flood plain with a stream channel running through its centre, opening into a stagnant lacustrine basin to the south. Gulf St Vincent would have become an open central drainage depression/basin complex. The Lacepede shelf would have been characterised by the extended Murray River system and its movement. Topographical changes were found to be most prevalent during sea-level transgression between 17,000 and 6,000 years cal. BP, which resulted in rapid inundation of the continental shelf. High levels of marine sedimentation are current within the gulf regions and Lacepede Shelf, with minimal sedimentation occurring across the Great Australian Bight region.

For the significance of investigating topographic changes in terms of its contribution to the Indigenous archaeological discourse, this study has demonstrated its role in creating circumstantial context of sites and its continued inclusion within future archaeological investigations concerning the Late Pleistocene and Early Holocene. By investigating the topographical changes which occurred in South Australia over the last 50,000 years, in addition to the radiocarbon calibration of archaeological site dates, this study was able to accurately contextualise archaeological sites within their contemporaneous landscape. With this context established, some initial interpretations could be made, where modelling of circumstantial context enables the highlighting of patterns in sites distribution across South Australia, and directions for future investigations.

Firstly, a gap is seen in the spatio-temporal locations of sites in South Australia during the Late Pleistocene, to the extent that between 50,000 and 13,000 years cal. BP, there is no recorded presence of coastal/marine sites in South Australia. Concurrently, archaeological sites are observed in the far west and far east of the state, with minimal presence recorded for the central area. Secondly, the spatial location of sites are found to be attributed to two key areas: Low-lying areas situated near floodplains, and elevated areas situated in mountainous or cliff/escarpment regions. Of the low-lying areas, these are only attributed to north-eastern sites whereas elevated areas are prevalent throughout the state. These spatial locations are determined to potentiality impact the current presence and locations of sites in the current landscape, with potential coastal and inland site locations on the shelf in known low-lying areas that are now underwater.

Thirdly, an identification of an archaeological site (or multiple sites) on the submerged continental shelf would be significant in terms of the knowledge acquired, whether purely by its location and site type (as a presence of human distribution in the past beyond the current coastline) or the materials located within the site (e.g. material shows either a continuation of know patterns recorded in other archaeological sites, or reveals new information about human activity). Finally, models used to display the spatio-temporal distribution of archaeological sites to analyse human activity need to be based on the circumstantial context. The fluidity of site distribution and landscape changes should be displayed as such to ensure site interpretations are based on the landscape contemporaneous to its use.

Avenues of further research into submerged continental shelf were recommended, specifically focused on the production of localised circumstantial contexts. Future archaeological investigations of the submerged continental shelf are encouraged for the gulf regions of South Australia and the Lacepede Shelf.

6.3 Conclusion

This study has conducted the first environmental archaeologically focused assessment of the submerged continental shelf of South Australia. It has provided an understanding of topographic changes within South Australian as context from which further archaeological investigations into the submerged continental shelf may begin. It has highlighted the significance of archaeological research concerning the submerged continental shelf, with emphasis on understanding the purposes of research agendas. It has also emphasised the need to continually test models concerned with depicting past human activities and behaviours. Through incorporating the submerged continental shelf into investigations, archaeologists can create a holistic approach to the study of human movement and activity within Australia.

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Appendices

Appendix 1: South Australian Archaeological Context

These tables were compiled from the Australian database created by Williams et al. (2014) and other sites discussed in text. The column titles DATA relates to the applicability of the dates for use in calibration and time-series analysis (Williams et al. 2014). The dates for Warratyi are derived from Hamm et al. (2016: Supplementary Information), Allen's Cave (radiocarbon methods) from Martin (1973:285) and Cane (2001:143). All dates in Table A and B are uncalibrated.

Table A: Late Pleistocene Archaeological Sites

SITE_NAME	LAB_CODE	AGE (years BP)	ERROR	METHOD	DATA
Allen's Cave	OXOD-AC150	10100	600	OSL	
Allen's Cave	OXOD-AC150	11100	900	TL	
Allen's Cave	ANU 1041	11950	250	Radiocarbon	Terrestrial
Allen's Cave	ANU 1042	20200	1000	Radiocarbon	Terrestrial
Allen's Cave	OXOD-AC390	39800	1100	OSL	
Balcoracana Creek	ANU-2527	12610	100	Radiocarbon	Terrestrial
Balcoracana Creek	ANU-2528	13660	600	Radiocarbon	Terrestrial
Balcoracana Creek	ANU-2526	13770	200	Radiocarbon	Unusable
Balcoracana Creek	BC25	48100	8900	TL	
Hawker Lagoon	SUA-1751	>13930	140	Radiocarbon	Unusable
Hawker Lagoon	SUA-2131	14770	270	Radiocarbon	Terrestrial
JSN Site - JSN/W3	ANU-7196	14400	200	Radiocarbon	Terrestrial
JSN Site - Wassons Hearth	ANU-2279	13150	830	Radiocarbon	Terrestrial
JSN Site - Wassons Hearth	ANU-2278	13850	190	Radiocarbon	Terrestrial

JSN Site - WJSN/N1 & N2	ANU-7197	10500	230	Radiocarbon	Terrestrial
Karolta 1	NZA-1369	12650	150	Radiocarbon	Unusable
Karolta 1	NZA-1414	12970	150	Radiocarbon	Unusable
Karolta 1	AA-6548	20105	185	Radiocarbon	Unusable
Karolta 1	AA-6905	21195	220	Radiocarbon	Unusable
Karolta 1	Not Given	22000	2000	Cation-Ratio	
Karolta 1	NZA-1366	22480	340	Radiocarbon	Unusable
Karolta 1	Not Given	23000	3000	Cation-Ratio	
Karolta 1	Not Given	24000	1500	Cation-Ratio	
Karolta 1	Not Given	29000	2000	Cation-Ratio	
Karolta 1	NZA-1378	30230	770	Radiocarbon	Unusable
Karolta 1	NZA-1370	31230	920	Radiocarbon	Unusable
Koonalda Cave	ANU-149	<10000	NA	Radiocarbon	Unusable
Koonalda Cave	Gak-510	13700	270	Radiocarbon	Terrestrial
Koonalda Cave	ANU-70	15850	320	Radiocarbon	Terrestrial
Koonalda Cave	ANU-71	19300	350	Radiocarbon	Terrestrial
Koonalda Cave	V-96	19300	720	Radiocarbon	Terrestrial
Koonalda Cave	ANU-148	19400	450	Radiocarbon	Terrestrial
Koonalda Cave	V-92	19900	2000	Radiocarbon	Terrestrial
Koonalda Cave	ANU-245	21900	540	Radiocarbon	Terrestrial
Koonalda Cave	ANU-244	23700	850	Radiocarbon	Terrestrial
Koonalda Cave	V-82	31000	1650	Radiocarbon	Terrestrial
Koonalda Cave	OXOD-KC200	58900	4600	OSL	
Koonalda Cave	OCOD-KC440	68700	5700	OSL	
NE Madigan Gulf	AA 12615	18450	165	Radiocarbon	Terrestrial
Panaramitee North	AA-6920	>43100		Radiocarbon	Unusable
Panaramitee North	AA-6898	43140	3000	Radiocarbon	Unusable
Roonka Flat Dune	ANU-406	18050	340	Radiocarbon	Terrestrial

Seton Rockshelter	ANU-925	10940	160	Radiocarbon	Terrestrial
Seton Rockshelter	ANU-1221	16100	1000	Radiocarbon	Terrestrial
Warratyi	Wk-35786	20585	70	Radiocarbon	
Warratyi	OZQ617	21080	70	Radiocarbon	
Warratyi	Wk-35787	22045	85	Radiocarbon	
Warratyi	Wk-40914	25900	180	Radiocarbon	
Warratyi	Wk-41180	29240	280	Radiocarbon	
Warratyi	Wk-36415	32340	350	Radiocarbon	
Warratyi	Wk-37317	34680	320	Radiocarbon	
Warratyi	Wk-36414	34990	490	Radiocarbon	
Warratyi	Wk-36413	35260	500	Radiocarbon	
Warratyi	Wk-39526	44100	2200	Radiocarbon	
Warratyi	OZQ616	44400	600	Radiocarbon	
Warratyi	Wk-37373	46300	2500	Radiocarbon	
Wharton Hill	NZA-1367	14910	180	Radiocarbon	Unusable
Wharton Hill	AA-6918	18485	165	Radiocarbon	Unusable
Wharton Hill	Not Given	27000	3500	Cation-Ratio	
Wharton Hill	NZA-2361	35530	650	Radiocarbon	Unusable
Wharton Hill	NZA-1356	36400	1700	Radiocarbon	Unusable
Wharton Hill	NZA-2180	37890	820	Radiocarbon	Unusable
Wharton Hill	AA-6907	>42000		Radiocarbon	Unusable
White Crossing (CC1510)	Wk-1510	11770	180	Radiocarbon	Terrestrial
White Crossing (CC77)	Wk-1509	11830	320	Radiocarbon	Terrestrial
Wyrie Swamp	ANU-1247	10200	150	Radiocarbon	Terrestrial
Wyrie Swamp	ANU-1292	10200	150	Radiocarbon	Terrestrial
Yunta Springs	AA-6914	13950	110	Radiocarbon	Unusable
Yunta Springs	Not Given	35000	5000	Cation-Ratio	

Table B: Early Holocene Archaeological Sites

SITE_NAME	**LAB_CODE**	**AGE (years BP)**	**ERROR**	**METHOD**	**DATA**
Allen’s Cave	ANU 1040	8780	140	Radiocarbon	Terrestrial
Allen’s Cave	ANU-6850	9270	150	Radiocarbon	Terrestrial
Allen’s Cave	ANU-6849	9530	190	Radiocarbon	Terrestrial
Balcoracana Creek	D3	9900	2200	TL	
Bevilaqua	Gak-423	6350	100	Radiocarbon	Marine

Bevilaqua	Gak-397	8250	60	Radiocarbon	Terrestrial
Cape Martin	R-55/4	8700	120	Radiocarbon	Terrestrial
Hawker Lagoon	Not Given	<8380	110	Radiocarbon	Unusable
Cape du Couedic	CS-610	6810	80	Radiocarbon	Terrestrial
Cape du Couedic	CS-495	7320	100	Radiocarbon	Terrestrial
Cape du Couedic	CS-496	7450	100	Radiocarbon	Terrestrial
Karolta 1	AA-6916	9125	100	Radiocarbon	Unusable
Karolta 1	AA-6910	9980	85	Radiocarbon	Unusable
Koonalda Cave	OXOD-KC5	9200	1100	OSL	
Koongine Cave	Beta-14859	8270	400	Radiocarbon	Terrestrial
Koongine Cave	Beta-21541	8900	110	Radiocarbon	Terrestrial
Koongine Cave	Beta-15996	9240	100	Radiocarbon	Terrestrial
Koongine Cave	Beta-14862	9590	140	Radiocarbon	Terrestrial
Koongine Cave	Beta-14861	9710	180	Radiocarbon	Terrestrial
Mt Burr	GaK-428	7030	40	Radiocarbon	Terrestrial
Mt Burr	GaK-427	7450	270	Radiocarbon	Terrestrial
Mt Burr	Gak-429	8600	300	Radiocarbon	Terrestrial
Roonka Flat Dune	ANU-1408	6910	450	Radiocarbon	Terrestrial
Roonka Flat Dune	ANU-1428	7480	440	Radiocarbon	Terrestrial
Wyrie Swamp	ANU-1377	7960	160	Radiocarbon	Terrestrial
Wyrie Swamp	ANU-1320	8210	110	Radiocarbon	Terrestrial
Wyrie Swamp	ANU-1192A	8470	150	Radiocarbon	Terrestrial
Wyrie Swamp	ANU-1192B	9010	120	Radiocarbon	Terrestrial
Wyrie Swamp	ANU-1490	9430	150	Radiocarbon	Terrestrial
Yunta Springs	AA-6909	7365	85	Radiocarbon	Unusable

Appendix 2: Secondary Sources Storage Information

Heading	**Information**
ID_Number	The identification number given to an individual source within its corresponding database.
Author_Last_Name	The first author's surname.
Author_First_Name	The first author's given name (and middle names in initials).
Other_Authors	The following authors' full name (first name, initials, then surname).
Year	The data the source was published or created.
Title	The title of the source (i.e. title of article, title of book etc.).
Journal/Periodical	The title of the journal/periodical in which the source was published (if applicable).
Volume/Issue	The corresponding volume and/or issue the source was published (if applicable).
Other	Other information relating to the sources' publication or creation (i.e. edition, editors).
Publisher	The organisation responsible to the publication of the source (if applicable).
Published_Location	The location in which the source was published (if applicable).
Published_Page_ Numbers	The pages numbers corresponding with a) the journal/periodical location in text or b) the edited chapter location (if applicable).
Referenced_Page_ Numbers	The page numbers corresponding with the location of the information contained in text.
Type	The type of the source (i.e. report, journal article, book chapter etc.).
Summary	A summary of the information contained in the source.
Original_File	The corresponding file that contains this source.
Physical_Location	The corresponding location from which the source was obtained.
Keywords	The keywords attributed to the information contained in this source.
Database_link	If a source is applicable to more than one database, then its associated database ID number is recorded here.

Appendix 3: Sea Level Data

The table below displays the 500 year averages determined from methods presented in section 3.1.1. Data from integrated Belperio et al. (2002), Lambeck (2004) and Lambeck et al. (2014). All dates and depths were corrected by original authors and users of the data.

Table C: Sea-level averages for 500 year periods.

Age Averages (Min - Max)	**Age Mean (years cal. BP)**	**Average Sea Level (m)**
0.000–0.249	0.000	0.000
0.250–0.749	0.500	–0.414
0.750–1.249	1.000	0.262
1.250–1.749	1.500	0.640
1.750–2.249	2.000	1.003
2.250–2.749	2.500	0.683
2.750–3.249	3.000	0.893
3.250–3.749	3.500	1.288
3.750–4.249	4.000	1.431
4.250–4.749	4.500	0.928
4.750–5.249	5.000	1.671
5.250–5.749	5.500	1.082
5.750–6.249	6.000	1.208
6.250–6.749	6.500	–0.394
6.750–7.249	7.000	–1.273
7.250–7.749	7.500	–4.250
7.750–8.249	8.000	–6.042
8.250–8.749	8.500	–10.149
8.750–9.249	9.000	–17.013
9.250–9.749	9.500	–24.916
9.750–10.249	10.000	–29.924
10.250–10.749	10.500	–34.909
10.750–11.249	11.000	–43.780
11.250–11.749	11.500	–54.585
11.750–12.249	12.000	–56.838
12.250–12.749	12.500	–58.600
12.750–13.249	13.000	–63.864
13.250–13.749	13.500	–70.443
13.750–14.249	14.000	–82.680
14.250–14.749	14.500	–91.932

14.750–15.249	15.000	–96.867
15.250–15.749	15.500	–101.133
15.750–16.249	16.000	–106.033
16.295	16.295	–105.200
16.750–17.249	17.000	–113.420
17.580	17.580	–109.600
17.750–18.249	18.000	–112.017
18.250–18.749	18.500	–110.033
18.750–19.249	19.000	–114.860
19.250–19.749	19.500	–113.875
20.042	20.042	–110.000
20.250–20.749	20.500	–125.400
21.000	21.000	–125.000
21.690	21.690	–119.100
21.750–22.249	22.000	–127.000
23.750–24.249	24.000	–130.700
24.476	24.476	–133.000
28.250–28.749	28.500	–117.850
28.750–29.249	29.000	–125.800
29.580	29.580	–118.400
29.750–30.249	30.000	–94.275
30.298	30.298	–86.000
31.250–31.749	31.500	–68.150
31.997	31.997	–76.800
32.250–32.749	32.500	–69.650
34.100	34.100	–63.000
34.800	34.800	–63.400
35.000	35.000	–73.000
36.000	36.000	–70.000
37.000	37.000	–65.000
38.000	38.000	–70.000
39.000	39.000	–74.000
40.000	40.000	–74.500
41.000	41.000	–74.000
42.000	42.000	–71.000
43.000	43.000	–67.000
44.000	44.000	–55.000
45.000	45.000	–60.000
46.000	46.000	–67.000
47.000	47.000	–68.000
48.000	48.000	–56.000
49.000	49.000	–47.000
50.000	50.000	–47.000

The table below displays the 1000 year sea-level averages determine from the previous table. This table was used for sea-level modelling.

Table D: Sea-level averages for 1000 year periods.

Age (years cal. BP)	**Depth (m)**
0	0
1000	0
2000	1
3000	1
4000	1
5000	2
6000	1
7000	–1
8000	–6
9000	–17
10000	–30
11000	–50
12000	–57
13000	–64
14000	–83
15000	–97
16000	–106
17000	–113
18000	–112
19000	–115
20000	–110
21000	–125
22000	–127
23000	–129
24000	–131
25000	–131
26000	–127
27000	–123
28000	–119
29000	–126
30000	–94
31000	–75
32000	–77
33000	–67
34000	–63
35000	–73
36000	–70
37000	–65
38000	–70
39000	–74
40000	–75
41000	–74
42000	–71
43000	–67
44000	–55
45000	–60
46000	–67
47000	–68
48000	–56
49000	–47
50000	–47

Appendix 4: Archaeological Data for Time-Series Analysis

Table E provides the results of the calibration of archaeological sites used in time-series analysis (landscape modelling of spatial distribution over time). The selection of sites and calibration process is outlined in section 3.1.2. Dates are displayed regardless of designation within Late Pleistocene and Early Holocene age brackets. These dates are by no means a comprehensive view of the time span of occupation at sites investigated in this study, but rather a snapshot of a shifting circumstantial context.

Table E: Archaeological Sites used in time-series analysis of landscape changes (C14 dates calibrated).

Site Name	Lab Code	Uncalibrated Age (BP)	Error	Calibration Age Range (cal. BP)	Mean Age for Landscape Modelling (cal. BP)	Calibration Program and Atmospheric Curve	Calibration Reference
Allen’s Cave	ANU 1040			9540–10190	9865	OxCal 4.2 and Int.Cal13	Munt et al. (2018)
Allen’s Cave	ANU-6850			10000–10400	10200	CALIB 3.0 and southern hemisphere curve (1993)	Murray and Roberts (1997:167)
Allen’s Cave	OXOD-AC150	10100	500		10100	OSL dating	Murray and Roberts (1997:167)
Allen’s Cave	ANU-6849			10200–10900	10550	CALIB 3.0 and southern hemisphere curve (1993)	Murray and Roberts (1997:167)
Allen’s Cave	OXOD-AC150	11100			11100	TL dating	Murray and Roberts (1997:167)
Allen’s Cave	ANU 1041			13280–14764	14022	OxCal 4.2 and Int.Cal13	Munt et al. (2018)
Allen’s Cave	OXOD-AC390	39800	1100		39800	OSL dating	Murray and Roberts (1997:167)

Balcoracana Creek	D3	9900	2200		9900	TL dating	Gardner et al. (1987)
Balcoracana Creek	ANU-2527	12610	100	14290-15209	14750	OxCal 4.3.2 and SHCal13	This study
Balcoracana Creek	ANU-2528	13660	600	14447-18295	16371	OxCal 4.3.2 and SHCal13	This study
Bevilaqua	Gak-423	6350	100	6979-7428	7204	OxCal 4.3.2 and SHCal13	This study
Bevilaqua	Gak-397	8250	60	9012-9400	9206	OxCal 4.3.2 and SHCal13	This study
Cape Martin	R-55/4	8700	120	9467-10151	9809	OxCal 4.3.2 and SHCal13	This study
Cape du Couedic	CS-610	6810	80	7481-7786	7634	OxCal 4.3.2 and SHCal13	This study
Cape du Couedic	CS-495	7320	100	7935-8334	8135	OxCal 4.3.2 and SHCal13	This study
Cape du Couedic	CS-496	7450	100	8018-8394	8206	OxCal 4.3.2 and SHCal13	This study
Hawker Lagoon	SUA-2131	14770	270	17273-18583	17928	OxCal 4.3.2 and SHCal13	This study
JSN Site - JSN/W3	ANU-7196	14400	200	16935-17991	17463	OxCal 4.3.2 and SHCal13	This study
JSN Site - Wassons Hearth	ANU-2279	13150	830	13486-18005	15746	OxCal 4.3.2 and SHCal13	This study
JSN Site - Wassons Hearth	ANU-2278	13850	190	16165-17309	16737	OxCal 4.3.2 and SHCal13	This study
JSN Site - WJSN/N1 & N2	ANU-7197	10500	230	11406-12749	12078	OxCal 4.3.2 and SHCal13	This study
Koonalda Cave	Gak-510	13700	270	15765-17340	16553	OxCal 4.3.2 and SHCal13	This study
Koonalda Cave	ANU-70	15850	320	18452-19923	19188	OxCal 4.3.2 and SHCal13	This study
Koonalda Cave	ANU-71	19300	350	22455-24020	23238	OxCal 4.3.2 and SHCal13	This study
Koonalda Cave	V-96	19300	720	21741-25211	23476	OxCal 4.3.2 and SHCal13	This study

Koonalda Cave	ANU-148	19400	450	22386-24420	23403	OxCal 4.3.2 and SHCal13	This study
Koonalda Cave	V-92	19900	2000	19870-30199	25035	OxCal 4.3.2 and SHCal13	This study
Koonalda Cave	ANU-245	21900	540	25165-27379	26272	OxCal 4.3.2 and SHCal13	This study
Koongine Cave	Beta-14859	8270	400	8329-10229	9279	OxCal 4.3.2 and SHCal13	This study
Koongine Cave	Beta-21541	8900	110	9603-10218	9911	OxCal 4.3.2 and SHCal13	This study
Koongine Cave	Beta-15996	9240	100	10196-10651	10424	OxCal 4.3.2 and SHCal13	This study
Koongine Cave	Beta-14862	9590	140	10501-11230	10866	OxCal 4.3.2 and SHCal13	This study
Koongine Cave	Beta-14861	9710	180	10504-11619	11062	OxCal 4.3.2 and SHCal13	This study
Mt Burr	GaK-428	7030	40	7705-7933	7819	OxCal 4.3.2 and SHCal13	This study
Mt Burr	GaK-427	7450	270	7687-8971	8329	OxCal 4.3.2 and SHCal13	This study
Mt Burr	Gak-429	8600	300	8774-10381	9578	OxCal 4.3.2 and SHCal13	This study
NE Madigan Gulf	AA 12615	18450	165	21856-22593	22225	OxCal 4.3.2 and SHCal13	This study
Roonka Flat Dune	ANU-1408	6910	450	6290-6890	6590	OxCal v.4.2.3 and SHCal13	Littleton et al. (2017)
Roonka Flat Dune	ANU-1428	7480	440	6740-8710	7725	OxCal v.4.2.3 and SHCal13	Littleton et al. (2017)
Roonka Flat Dune	ANU-406	18150	340	21017-22674	21846	OxCal 4.3.2 and SHCal13	This study

Seton Rockshelter	NZA25830	9653	40	10700–11200	10950	OxCal v4.1.7 and SHCal13	McDowell et al. (2015)
Seton Rockshelter	NZA25831	10430	40	12000–12500	12250	OxCal v4.1.7 and SHCal13	McDowell et al. (2015)
Seton Rockshelter	ANU-925	10940	160	12400–13200	12800	OxCal v4.1.7 and SHCal13	McDowell et al. (2015)
Seton Rockshelter	NZA25832	13596	50	16100–16600	16350	OxCal v4.1.7 and SHCal13	McDowell et al. (2015)
Warratyi	Wk-35786	20585	70	24400–25050	24750	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	OZQ617	21080	70	25150–25600	25400	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	Wk-35787	22045	85	26000–26500	26200	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	Wk-40914	25900	180	29550–30600	30100	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	Wk-41180	29240	280	32750–33950	33350	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	Wk-36415	32340	350	35400–37300	36250	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	Wk-37317	34680	320	38500–39900	39200	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	Wk-36414	34990	490	38500–40600	39500	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	Wk-36413	35260	500	38750–40850	39800	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	Wk-39526	44100	2200	>44750	47300	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
Warratyi	OZQ616	44400	600	46300–49200	47750	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)

Warratyi	Wk-37373	46300	2500	>46000	48200	OxCal v4.2.4 and SHCal13	Hamm et al. (2016)
White Crossing (CC1510)	Wk-1510	11770	180	13205-14004	13605	OxCal 4.3.2 and SHCal13	This study
White Crossing (CC77)	Wk-1509	11830	320	13025-14797	13911	OxCal 4.3.2 and SHCal13	This study
Wyrie Swamp	ANU-1377	7930	160	8386-9233	8810	OxCal 4.3.2 and SHCal13	This study
Wyrie Swamp	ANU-1320	8210	110	8771-9444	9108	OxCal 4.3.2 and SHCal13	This study
Wyrie Swamp	ANU-1192A	8470	150	9011-9760	9386	OxCal 4.3.2 and SHCal13	This study
Wyrie Swamp	ANU-1192B	9010	120	9679-10406	10043	OxCal 4.3.2 and SHCal13	This study
Wyrie Swamp	ANU-1490	9430	150	10250-11104	10297	OxCal 4.3.2 and SHCal13	This study
Wyrie Swamp	ANU-1274	10200	150	11270-12398	11834	OxCal 4.3.2 and SHCal13	This study
Wyrie Swamp	ANU-1292	10200	150	11270-12398	11834	OxCal 4.3.2 and SHCal13	This study

Appendix 5: Landscape Modelling

Appendix 5a: Discrete Landscapes

Figure 5a.1: Topography between 50,000 to 46,000 years cal. BP.

Figure 5a.2: Topography between 45,000 to 42,000 years cal. BP.

Figure 5a.3: Topography between 41,000 to 38,000 years cal. BP.

Figure 5a.4: Topography between 37,000 to 34,000 years cal. BP.

Figure 5a.5: Topography between 33,000 to 30,000 years cal. BP.

Figure 5a.6: Topography between 29,000 to 26,000 years cal. BP.

Figure 5a.7: Topography between 25,000 to 21,000 years cal. BP.

Figure 5a.8: Topography between 20,000 to 17,000 years cal. BP.

Figure 5a.9: Topography between 16,000 to 13,000 years cal. BP.

Figure 5a.10: Topography between 12,000 to 9,000 years cal. BP.

Figure 5a.11: Topography between 8,000 to 5,000 years cal. BP.

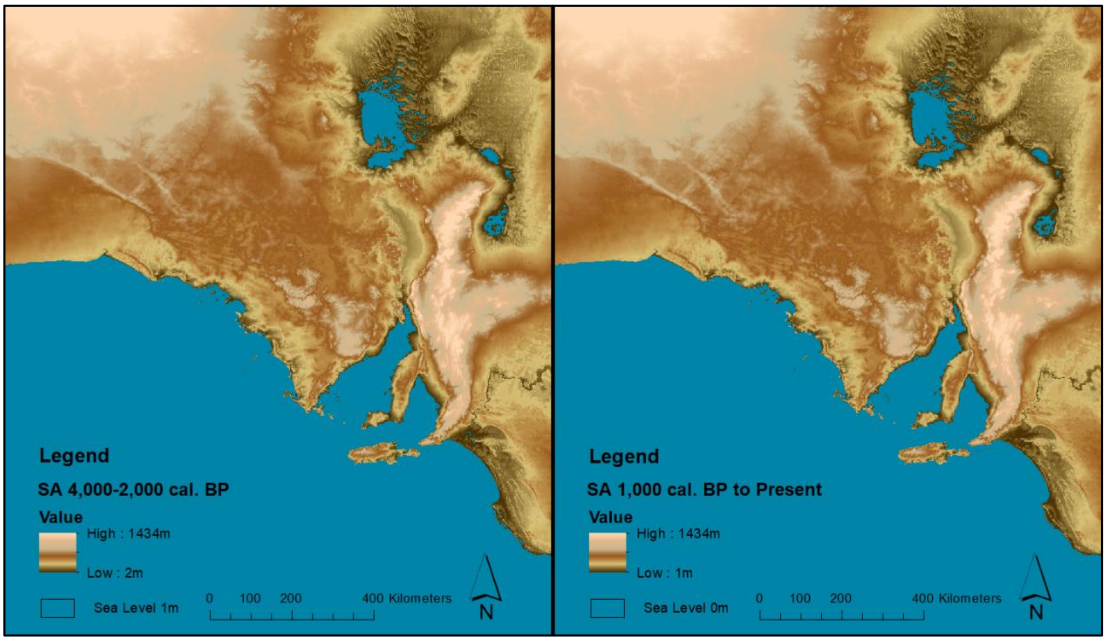

Figure 5a.12: Topography between 4,000 years cal. BP to Present.

Appendix 5b: Archaeology Sites in Context

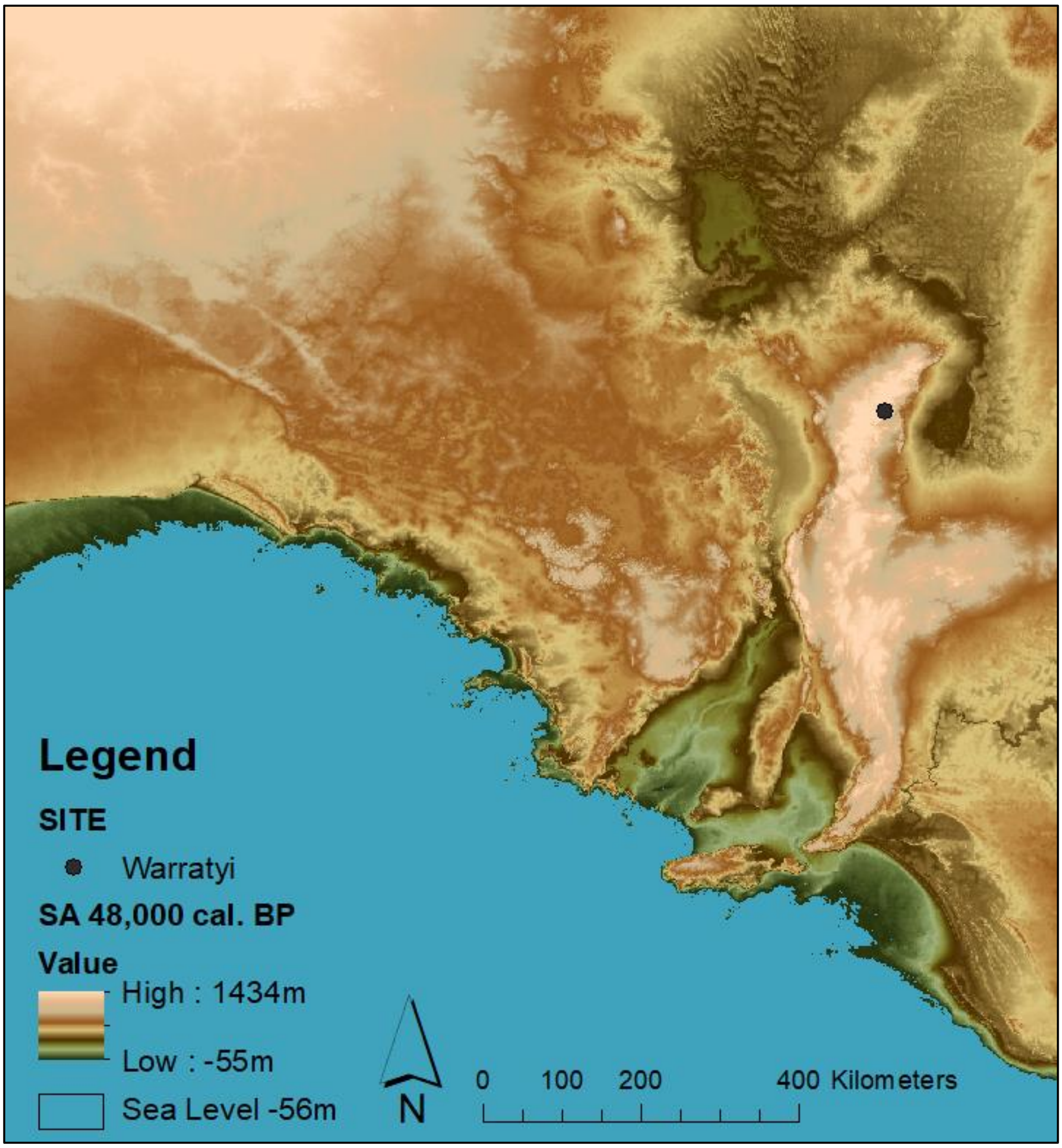

Figure 5b.1: Sites at 48,000 years cal. BP.

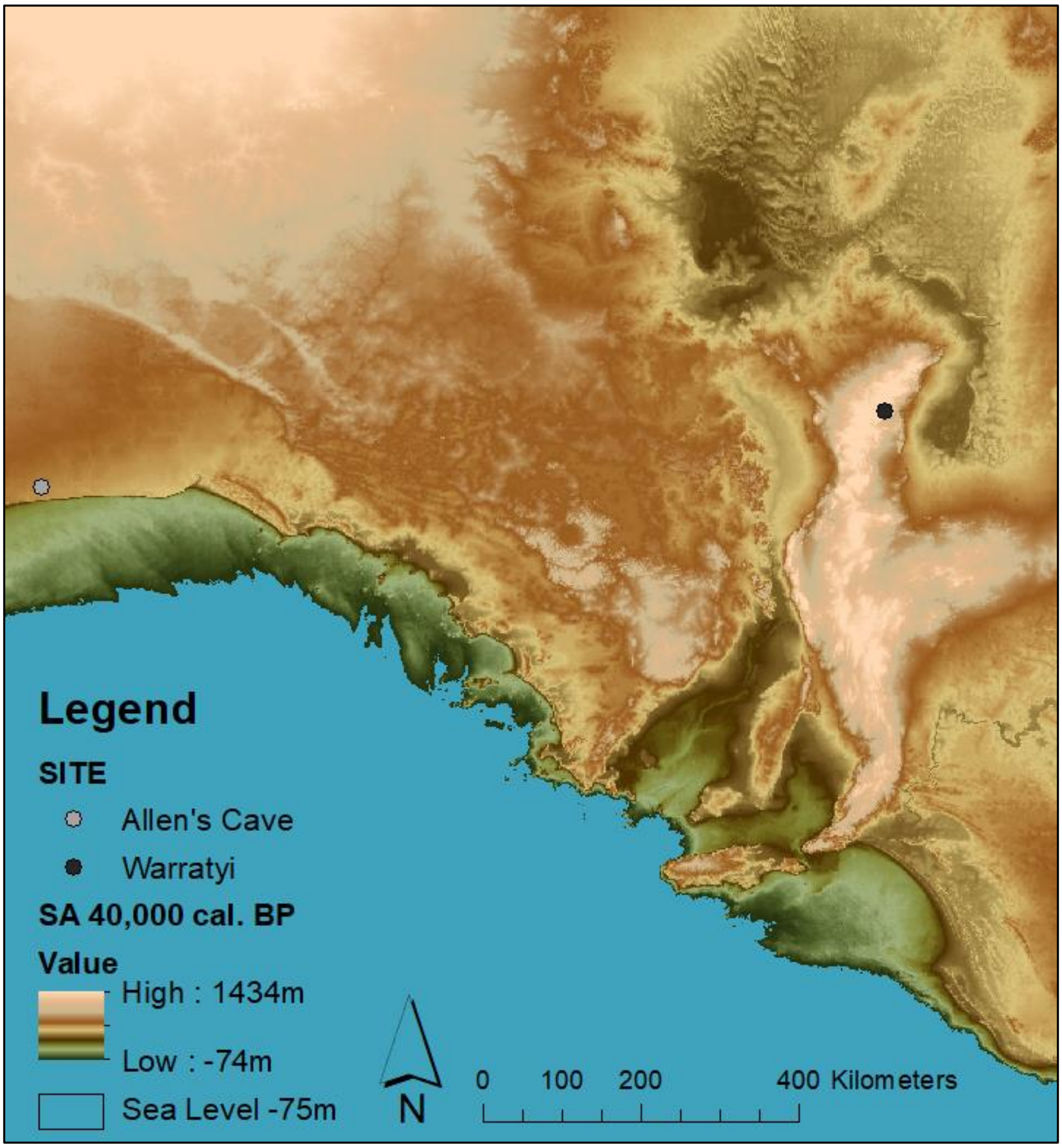

Figure 5b.2: Sites at 40,000 years cal. BP.

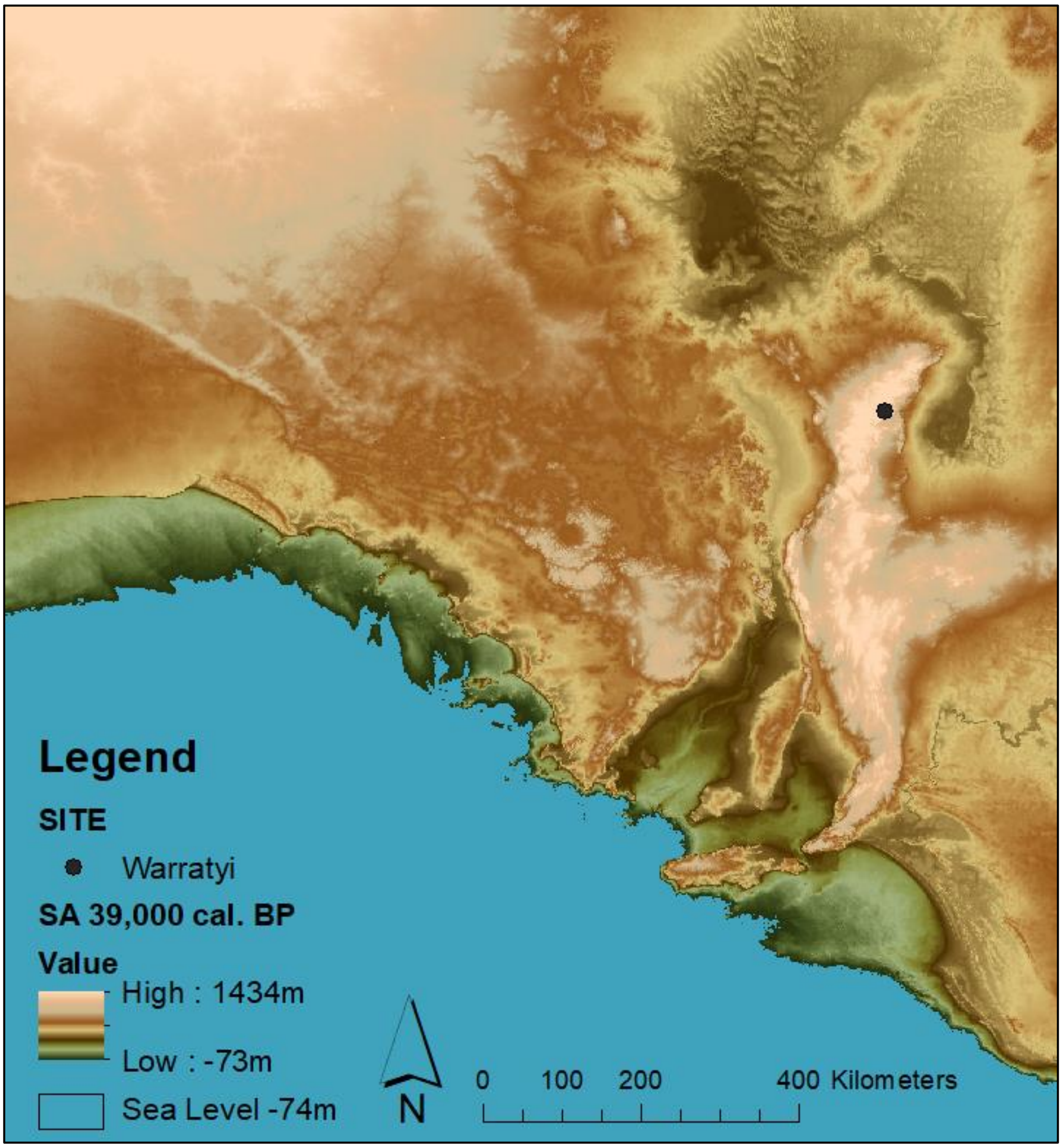

Figure 5b.3: Sites at 39,000 years cal. BP.

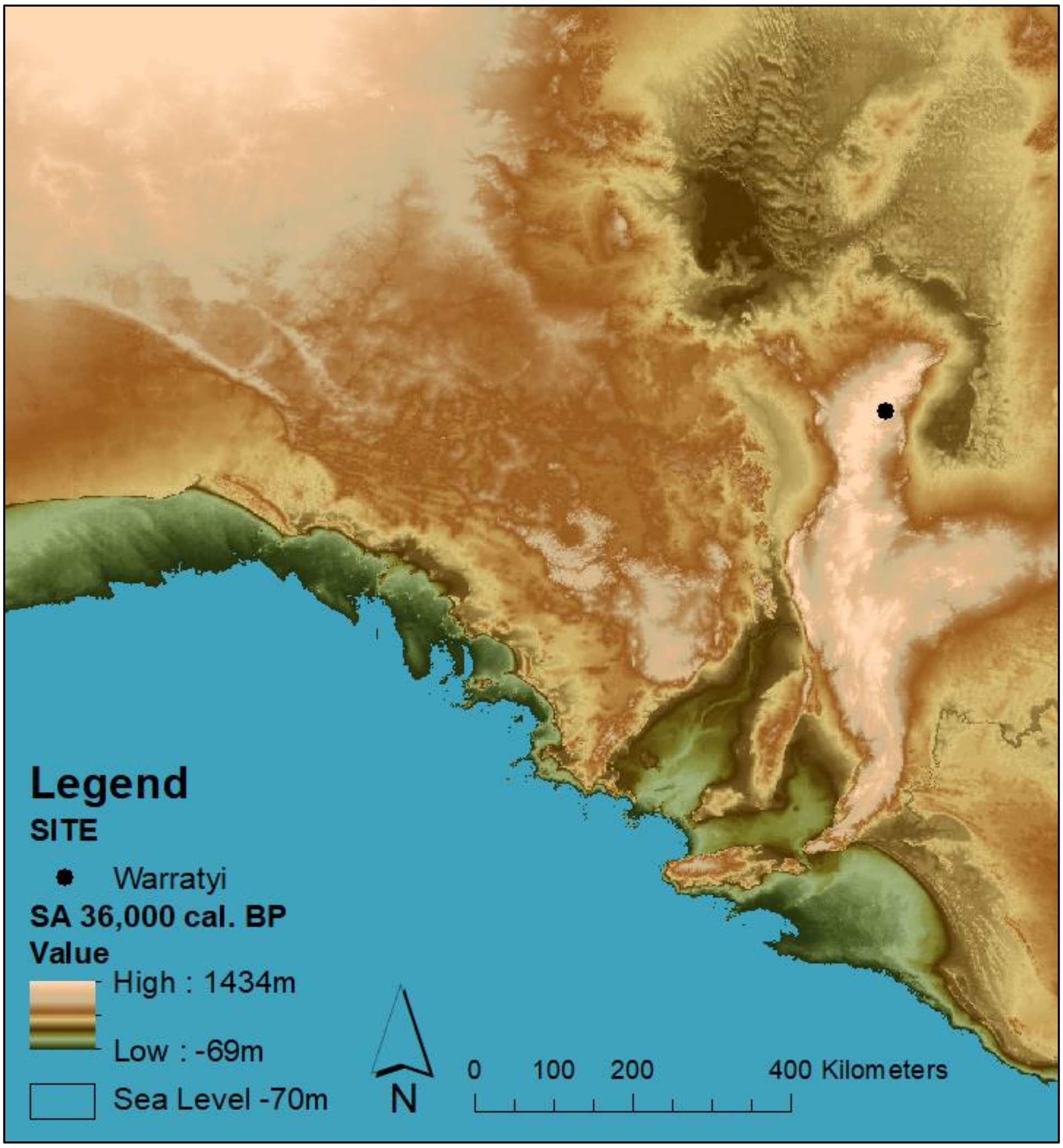

Figure 5b.4: Sites at 36,000 years cal. BP.

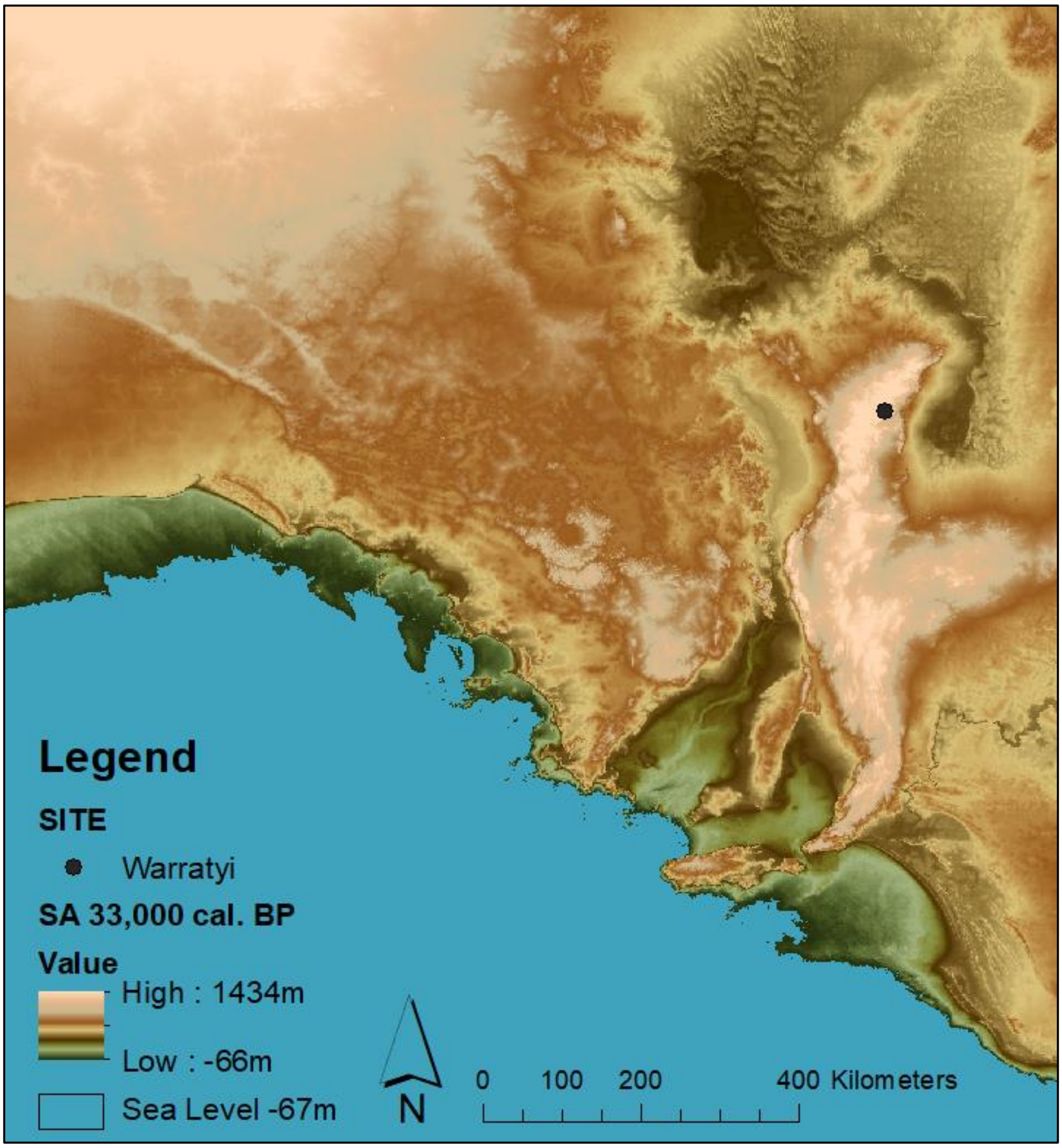

Figure 5b.5: Sites at 33,000 years cal. BP.

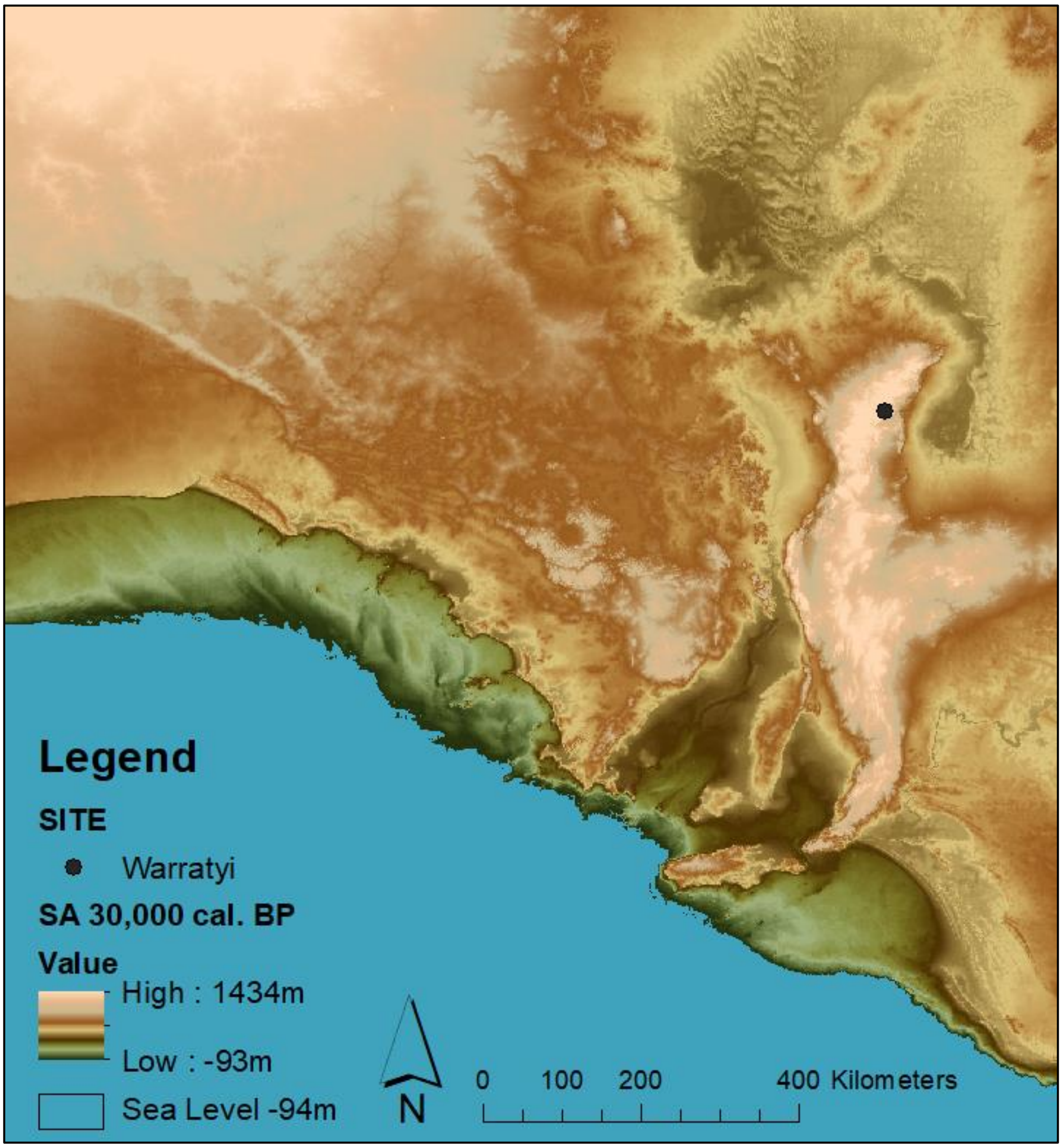

Figure 5b.6: Sites at 30,000 years cal. BP.

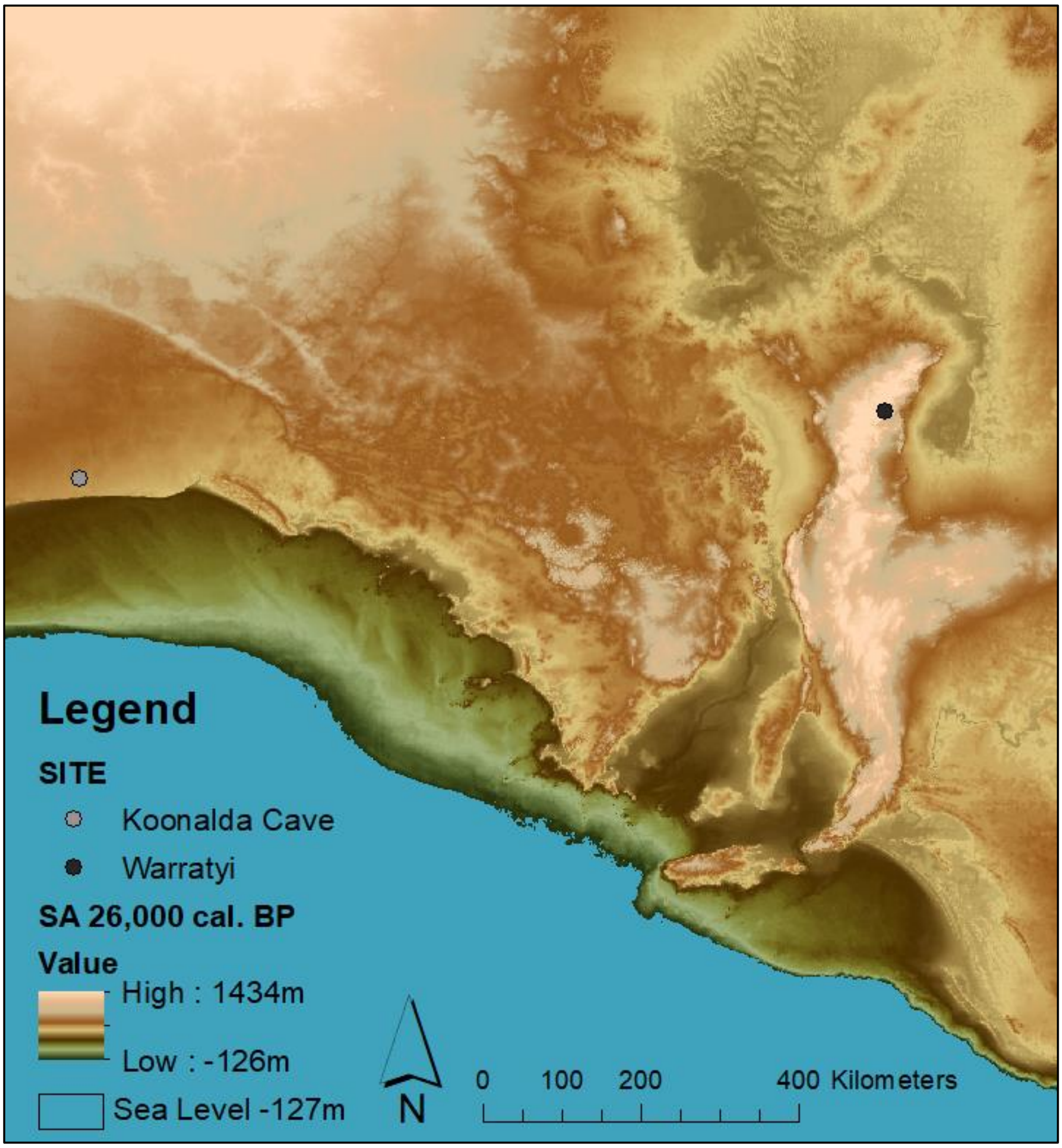

Figure 5b.7: Sites at 26,000 years cal. BP.

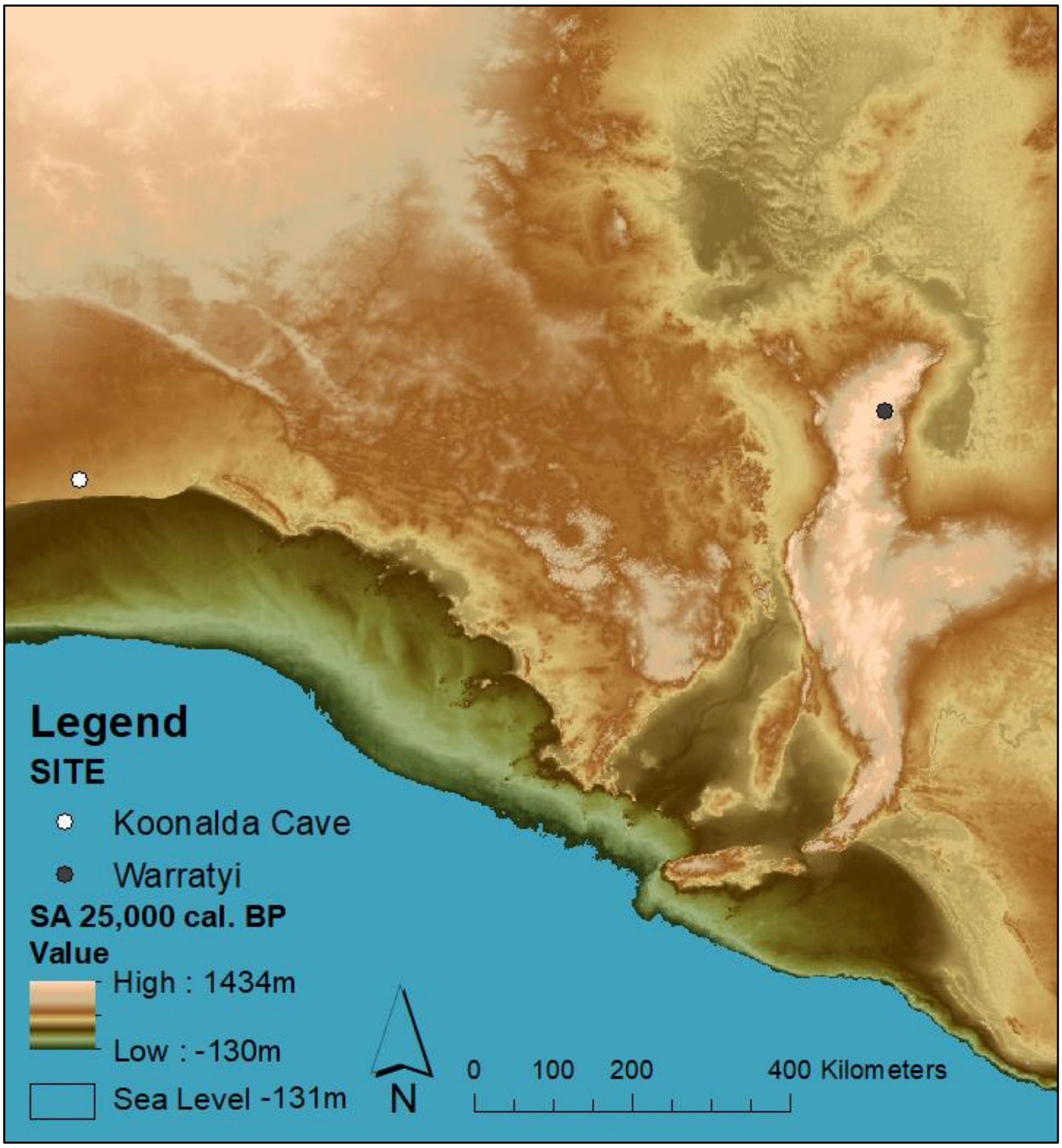

Figure 5b.8: Sites at 25,000 years cal. BP.

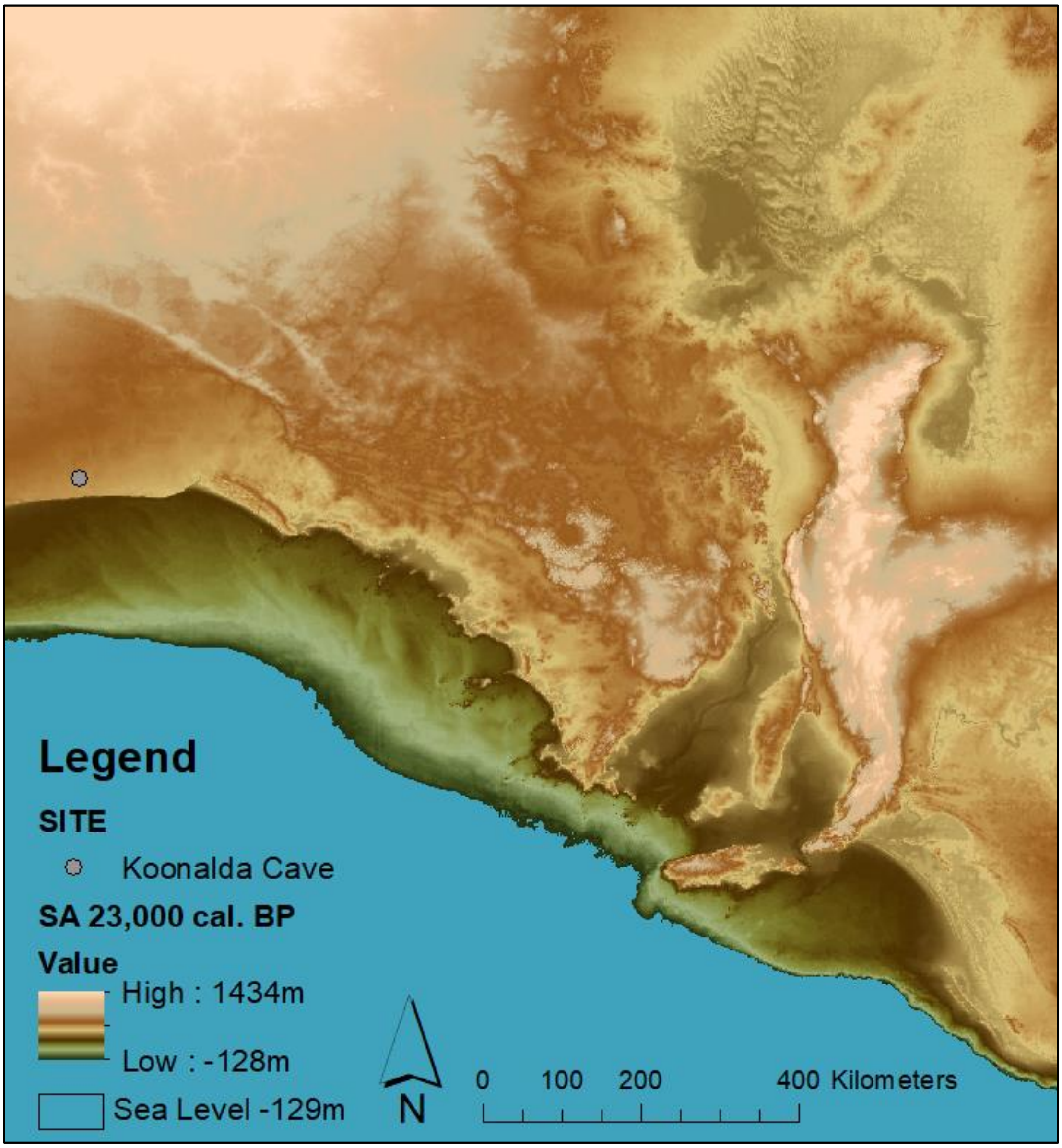

Figure 5b.9: Sites at 23,000 years cal. BP.

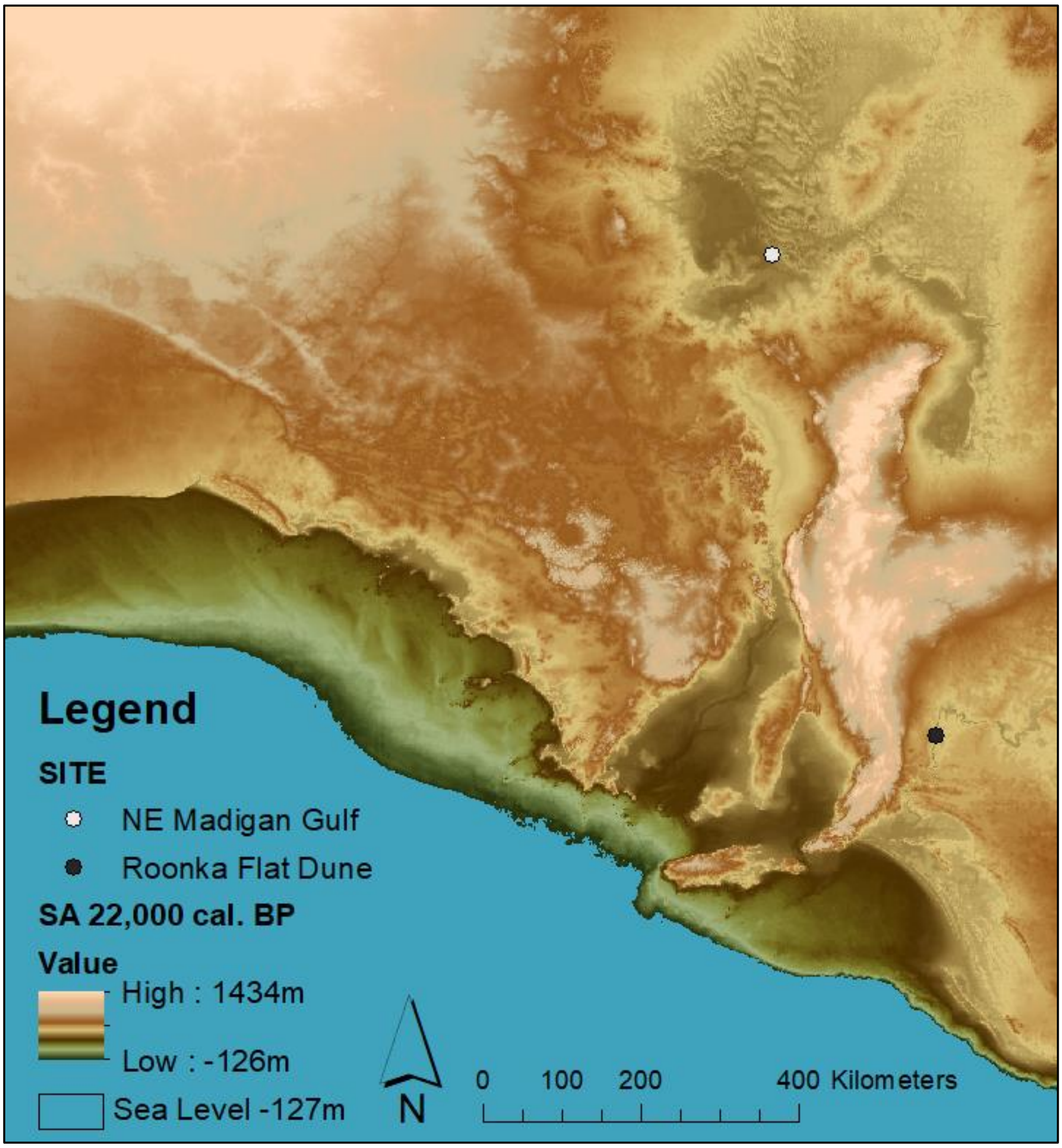

Figure 5b.10: Sites at 22,000 years cal. BP.

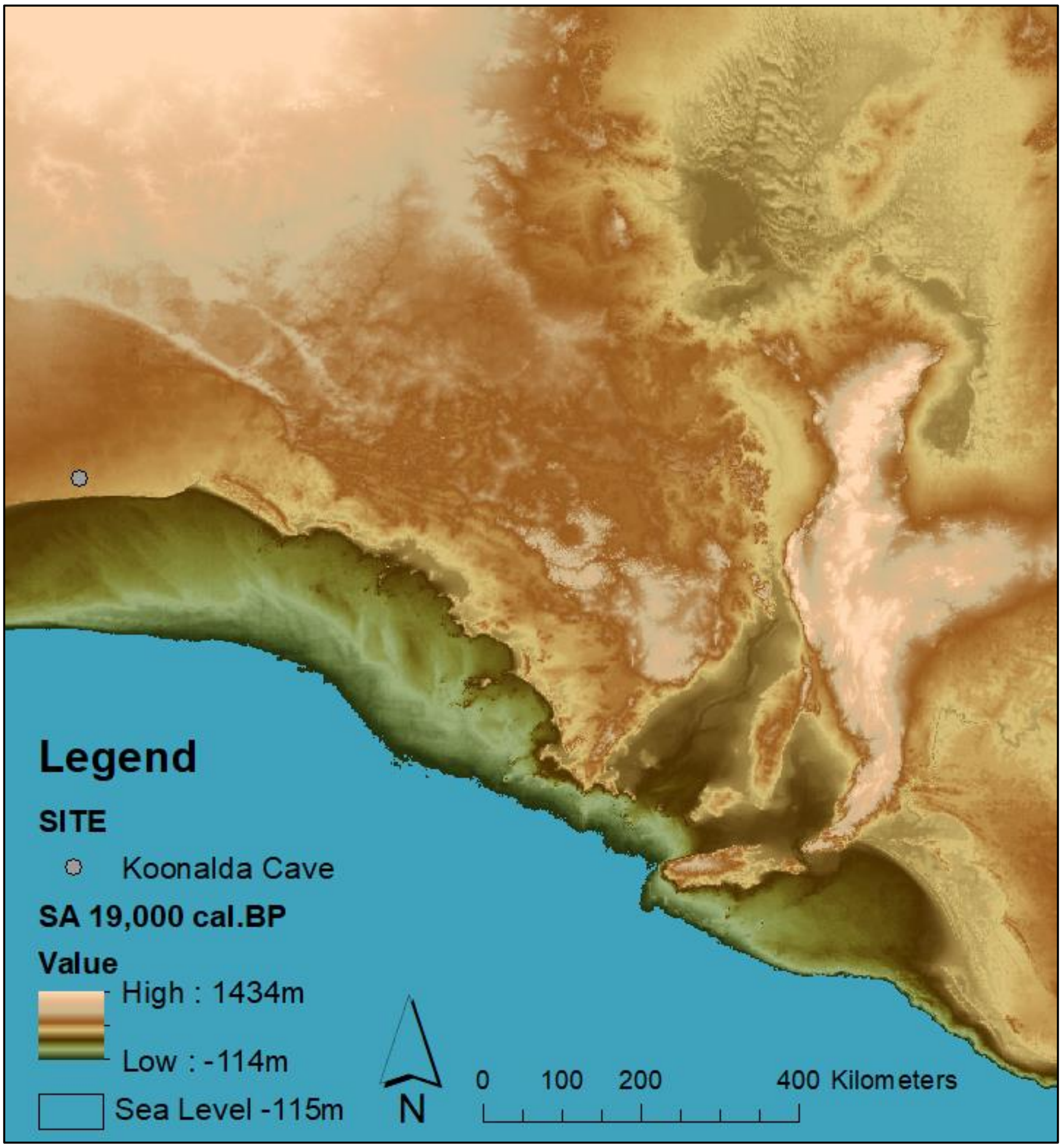

Figure 5b.11: Sites at 19,000 years cal. BP.

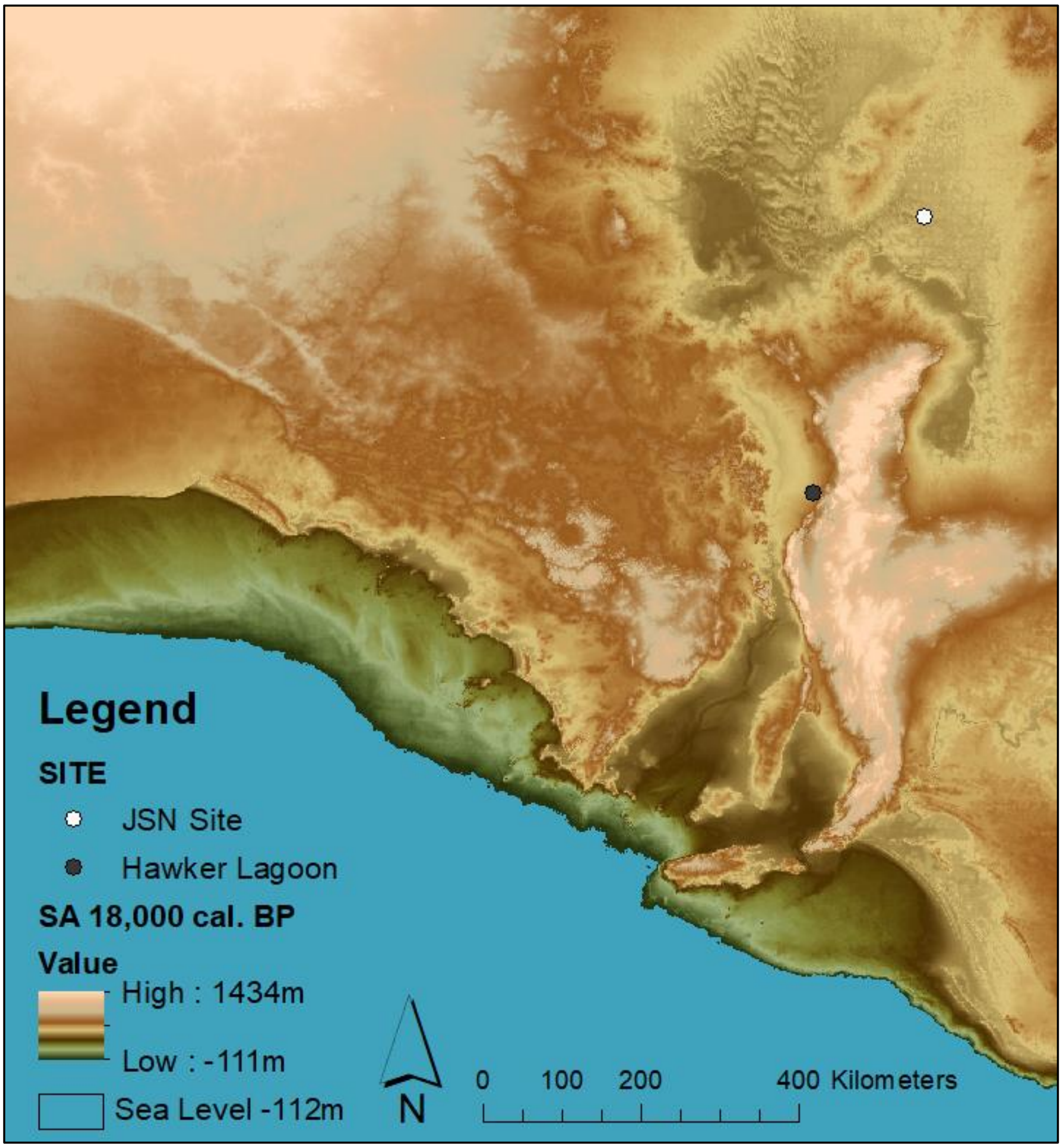

Figure 5b.12: Sites at 18,000 years cal. BP.

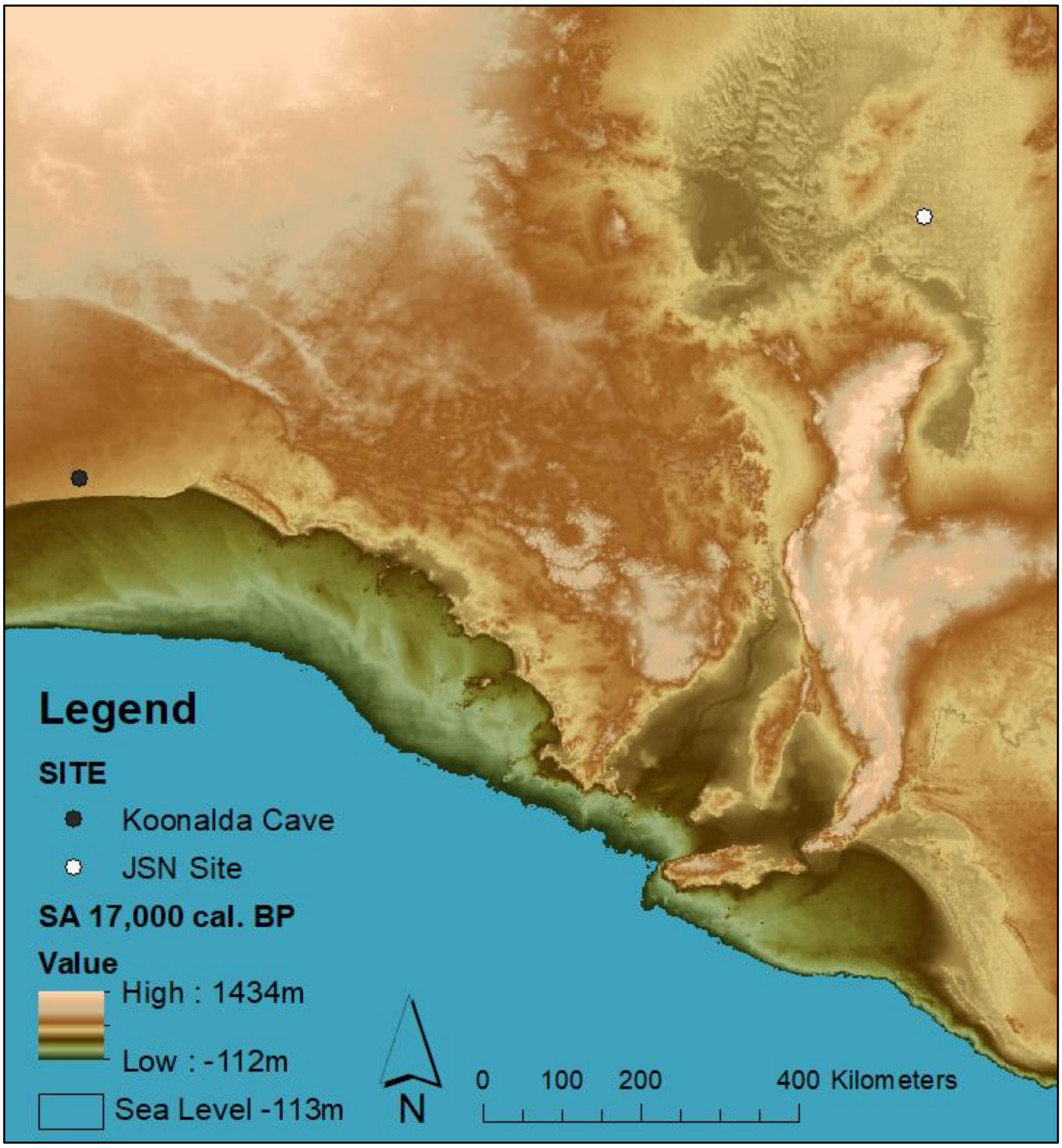

Figure 5b.13: Sites at 17,000 years cal. BP.

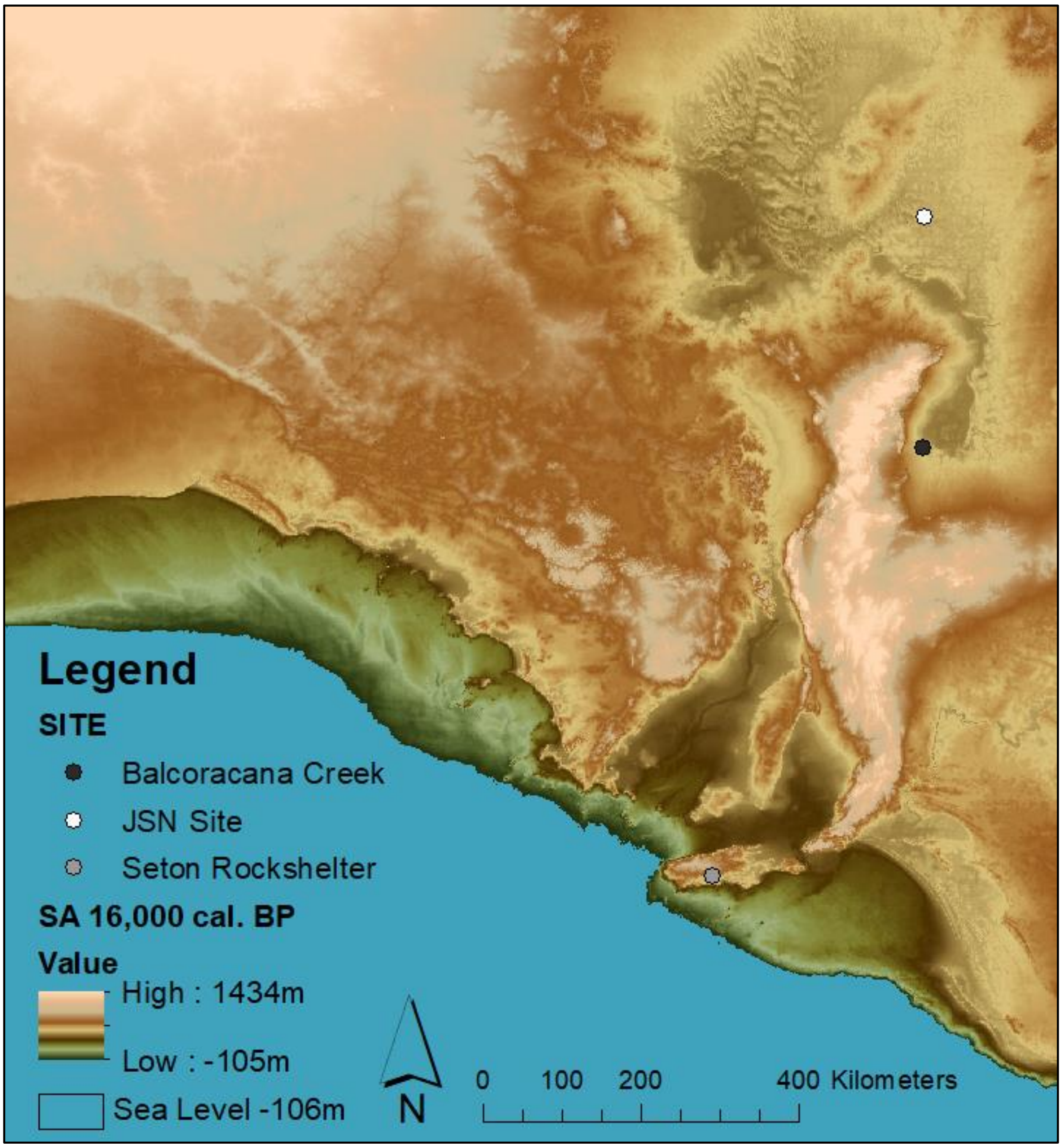

Figure 5b.14: Sites at 16,000 years cal. BP.

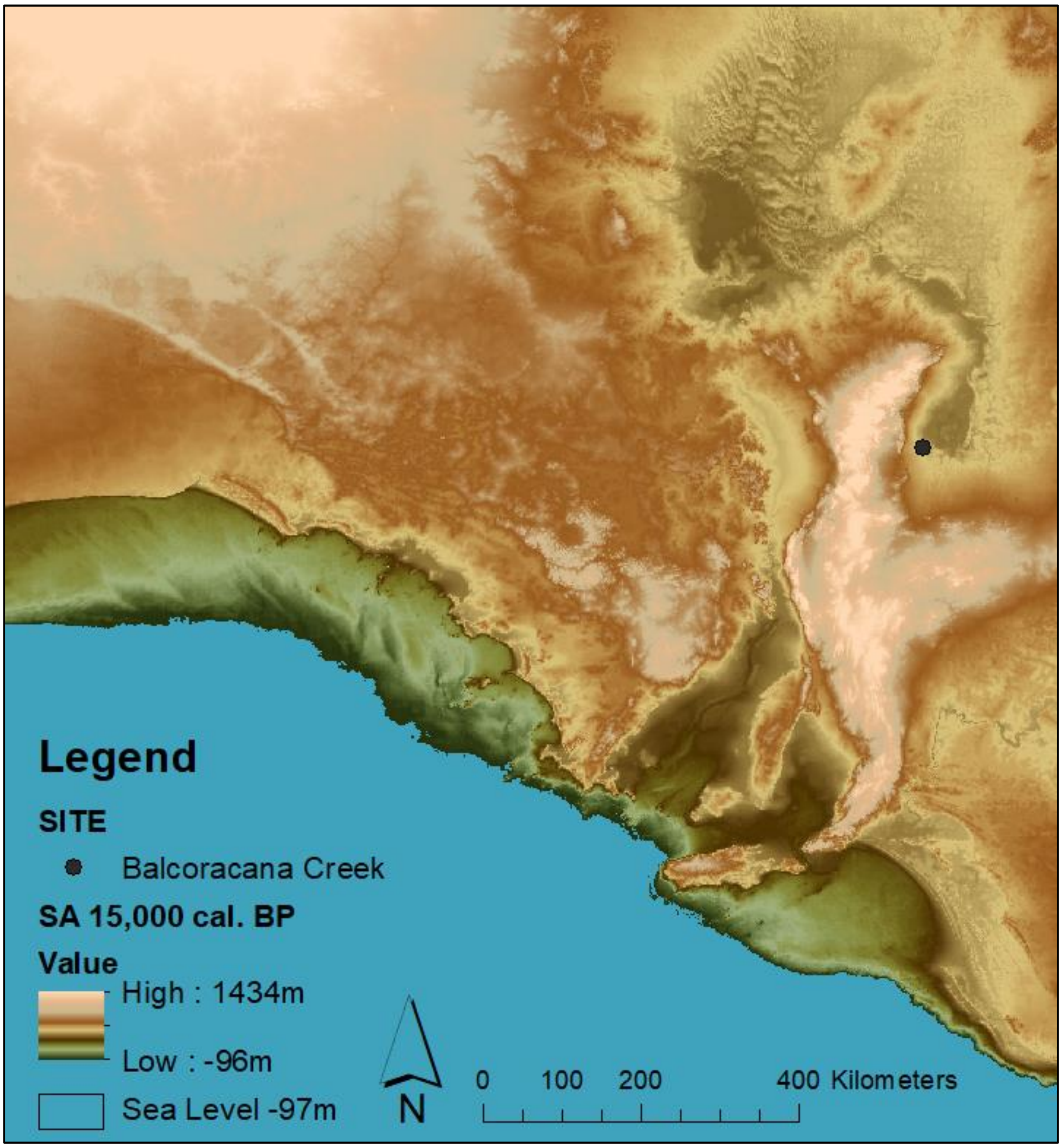

Figure 5b.15: Sites at 15,000 years cal. BP.

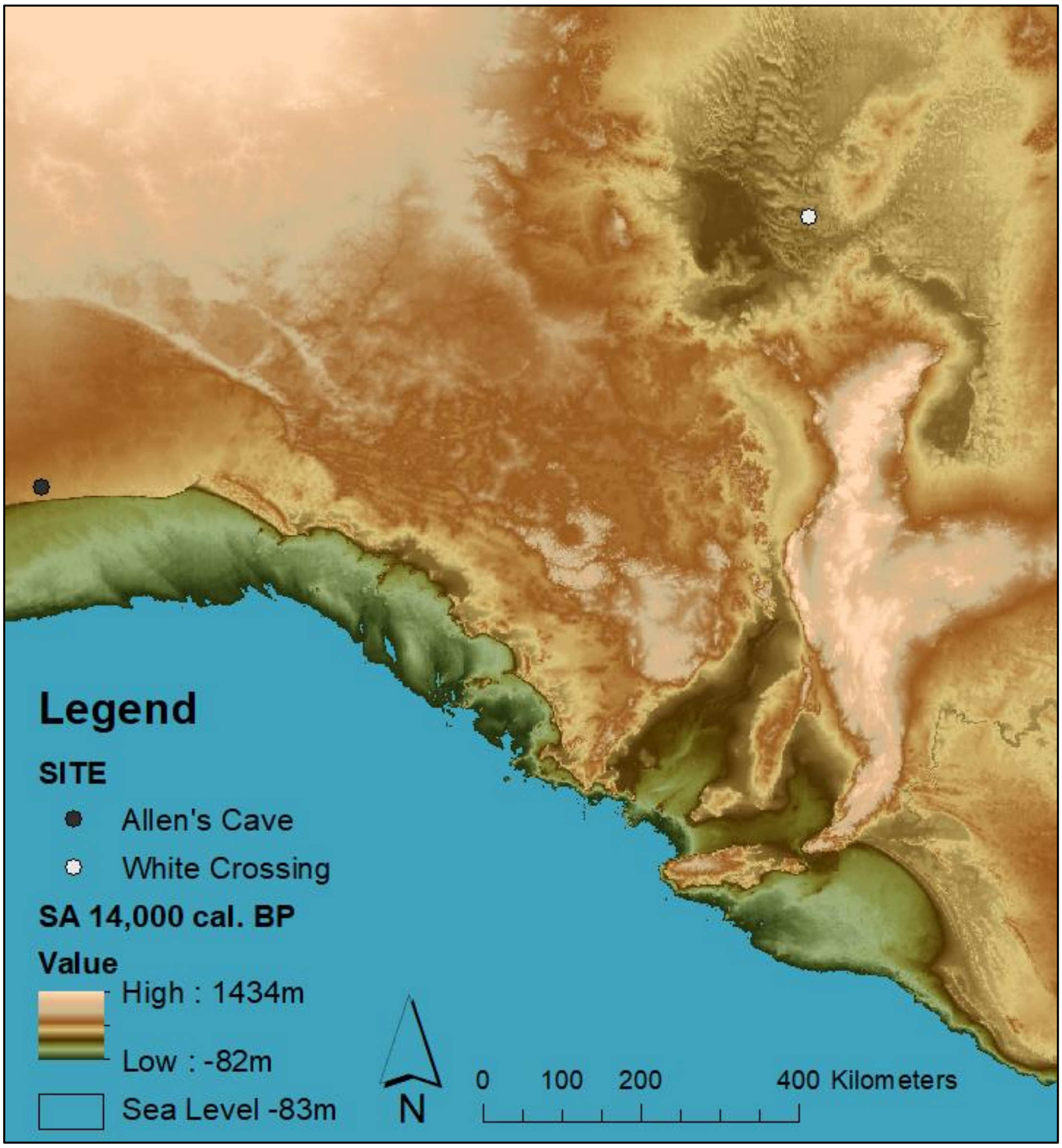

Figure 5b.16: Sites at 14,000 years cal. BP.

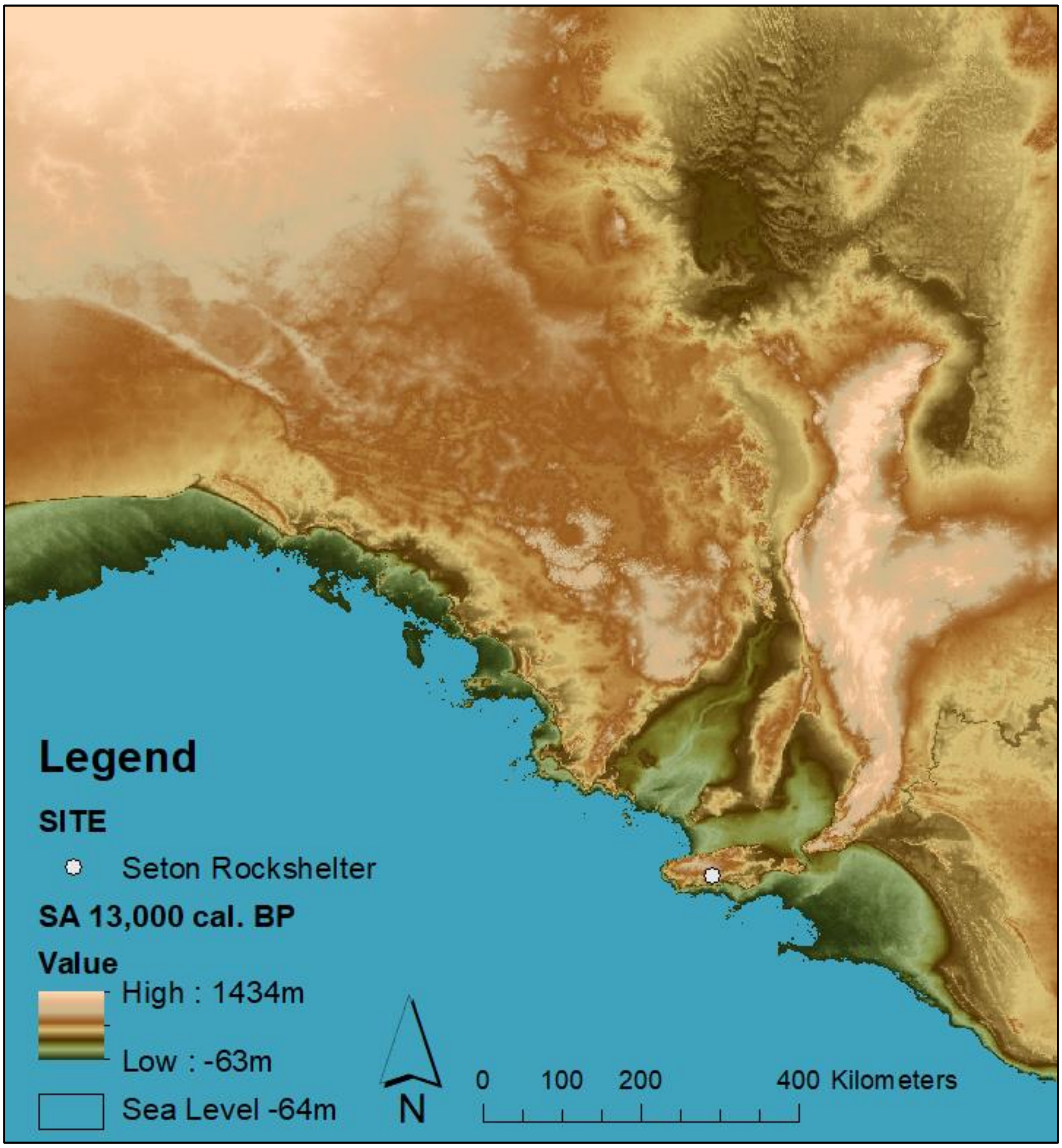

Figure 5b.17: Sites at 13,000 years cal. BP.

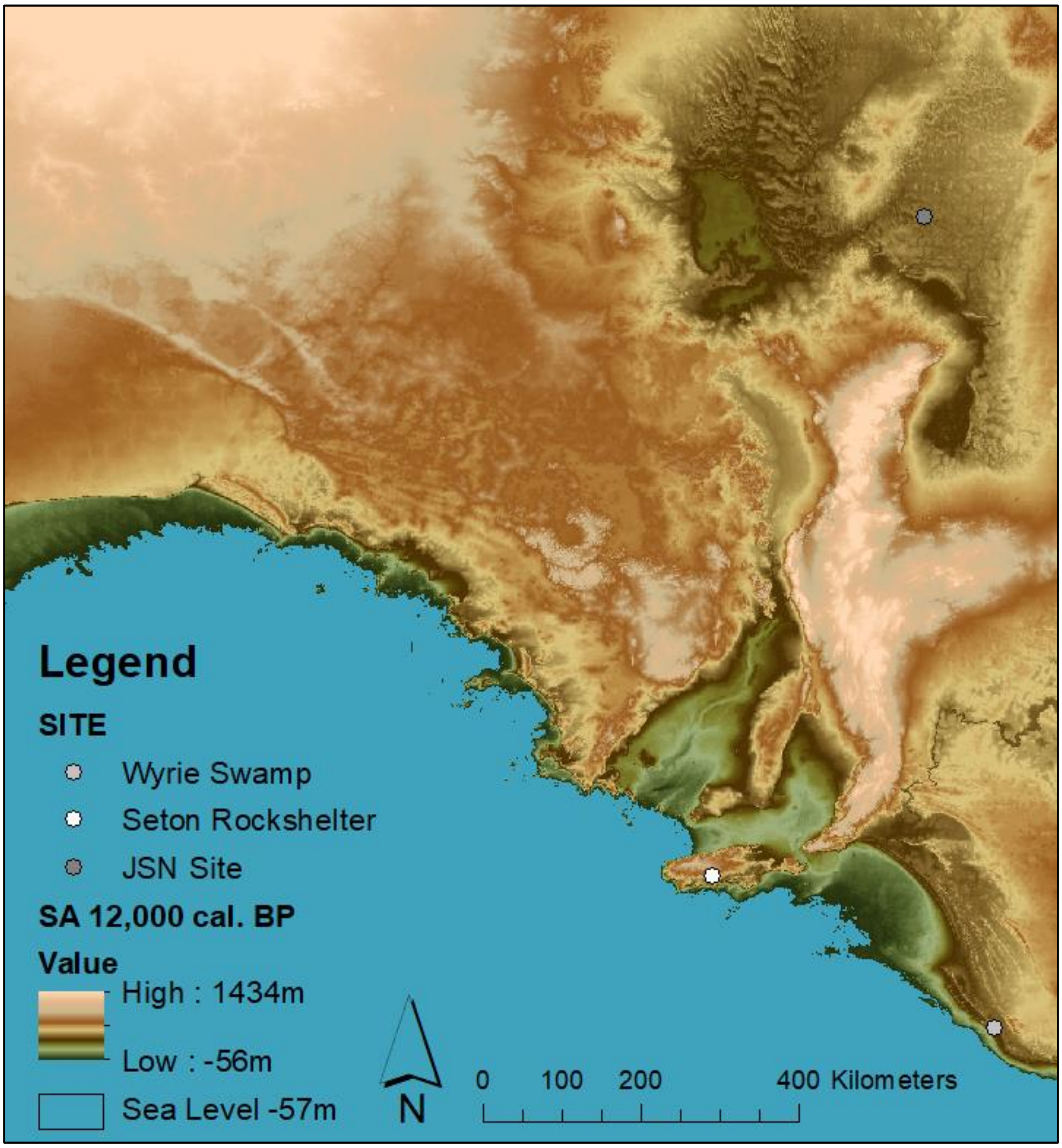

Figure 5b.18: Sites at 12,000 years cal. BP.

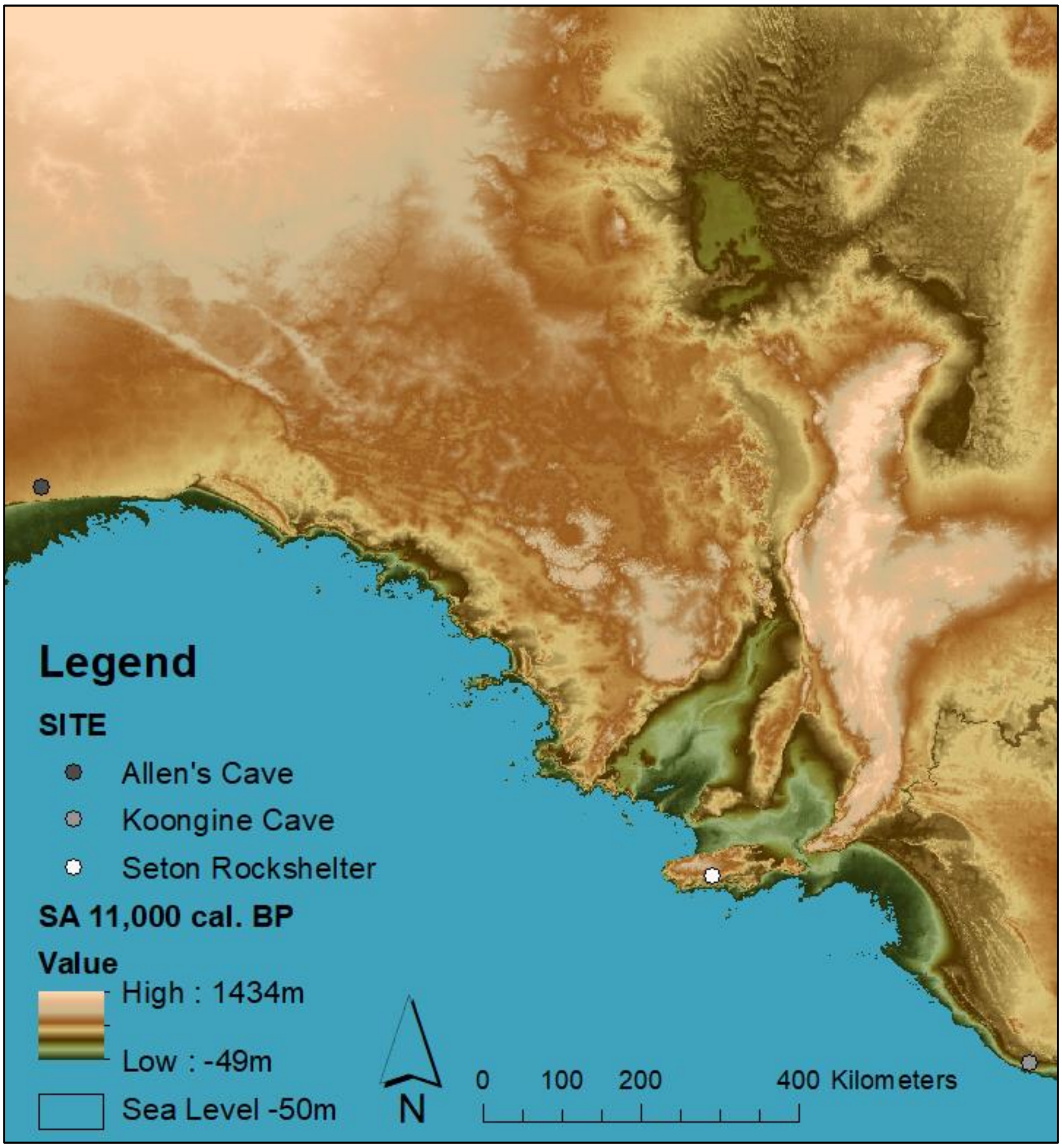

Figure 5b.19: Sites at 11,000 years cal. BP.

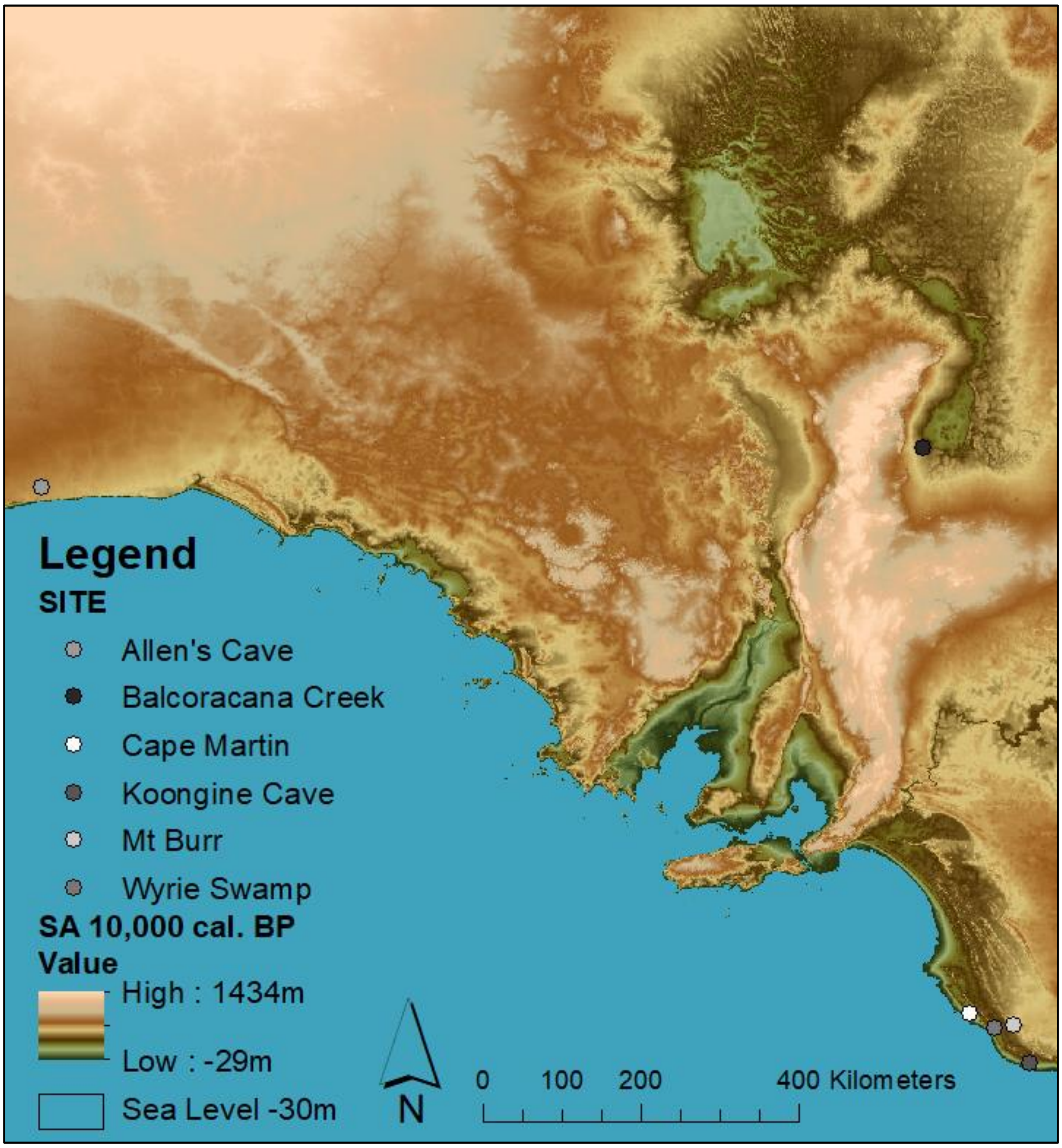

Figure 5b.20: Sites at 10,000 years cal. BP.

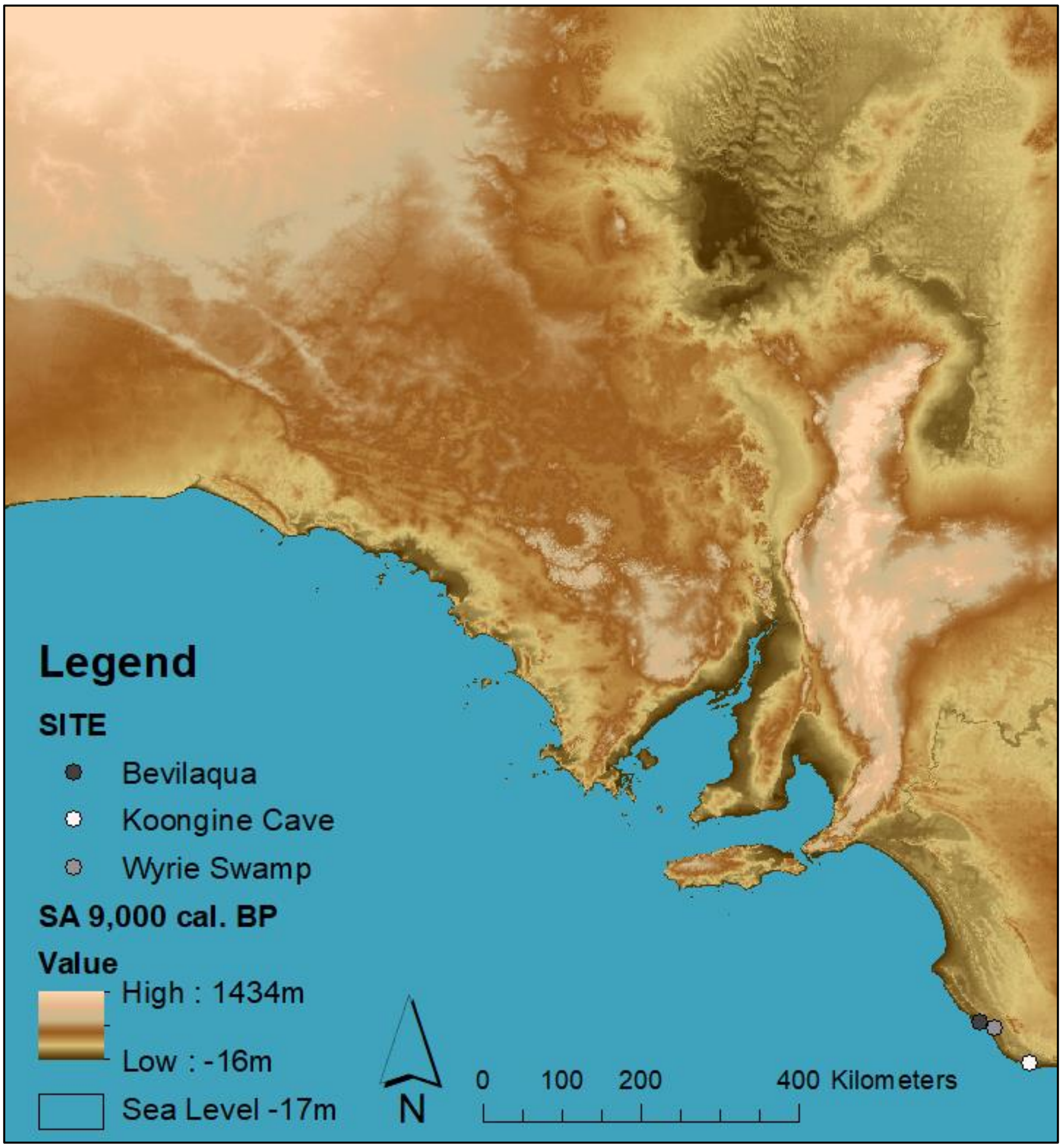

Figure 5b.21: Sites at 9,000 years cal. BP.

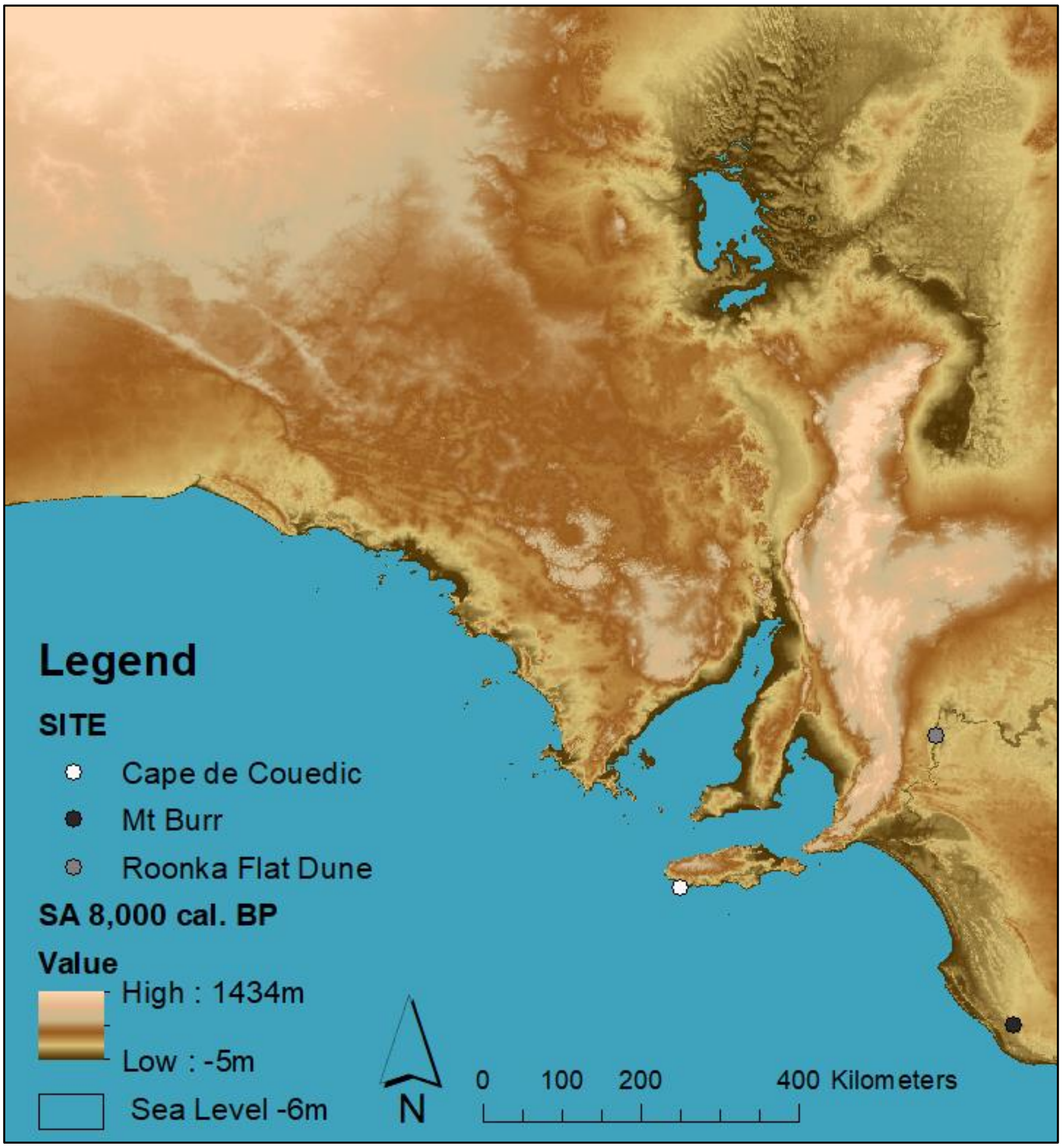

Figure 5b.22: Sites at 8,000 years cal. BP.

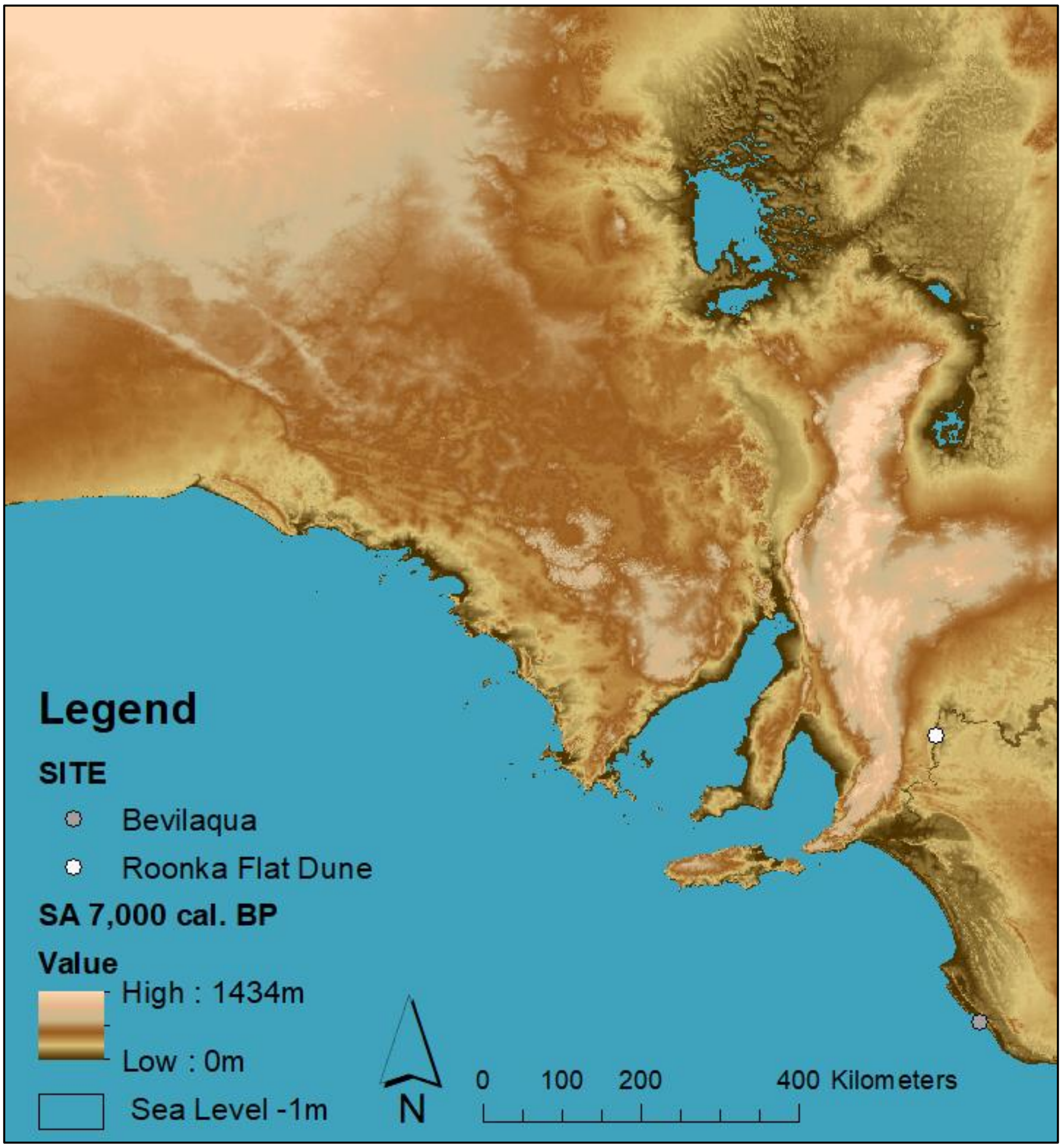

Figure 5b.23: Sites at 7,000 years cal. BP.