Australian Submerged Cultural Landscapes in Context: Examining an Onshore and Offshore Site at Withnell Bay, Murujuga

By

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ABSTRACT

Withnell Bay is located to the north of Western Australia and was chosen as a prospective site for the preservation of cultural materials found in sub-tidal contexts. This was based on the identification of a lithic artefact found in the intertidal zone in 2022 by Professor Peter Veth (University of Western Australia). In August and September 2023, a further nine underwater lithic artefacts were recovered from the northern coast of Withnell Bay with two distinct clusters located to the east and west. The purpose of this study is to demonstrate that submerged landscape archaeology benefits from contextual based inquiry which aims to connect underwater sites to the broader terrestrial landscape. This was achieved through the analysis of published archaeological and geomorphological literature and systematic pedestrian survey of the intertidal zone. Identified in this study were archaeological sites such as petroglyphs, lithic scatters and quarrying along with stone features which occurred frequently around exposed outcrops of granophyre in the nearshore environment. The size and morphology of the intertidal artefacts when compared to the underwater lithics demonstrated that there were two clusters, as the eastern assemblage was distinctively different to the western site and are likely from different ages and activities. The western site situated near the headland to the northwest of Withnell Bay extends across the onshore and offshore environment and may have been used both pre-and-post sea-level stabilisation. Whereas the eastern underwater assemblage which is situated closer to the mangroves has similar features to intertidal artefacts and due to the artefact morphology, may represent a site that dates to the late-Pleistocene or early-Holocene. This study was a formative exploration of the submerged archaeological landscape of Withnell Bay and aimed to assess the terrestrial, intertidal and sub-tidal environment to contextualise the northern coastline through periods of sea-level change, representing a cultural continuum both on-land and underwater.

DECLARATION

I, Louise Brooke, certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university

2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and

3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Signed:

Date: 1/06/2024

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LIST OF ABBREVIATIONS

Cal BP – Calibrated Years Before Present

CBC – Cape Bruguieres Channel

CM – Centimetre

DECRA – Discovery Early Career Research Award

DHSC – Deep History of Sea Country

FFP – Flying Foam Passage

GIA – Glacial Isostatic Adjustment

Intertidal – The area between mean high water and mean low water

LGM – Last Glacial Maximum

M – Metres

MAC – Murujuga Aboriginal Corporation

MHW – Mean High Water

MLW – Mean Low Water

MHWS – Mean High-Water Spring

MLWS – Mean Low-Water Spring

NSW – New South Wales

NT – Northern Territory

NW – North-West

NW-H – North-West Headland

NWS – North-West Shelf

Orthomosaic – Photogrammetrically orthorectified image

OSL – Optically Stimulated Luminescence

PGR – Post Glacial Rebound

pXRF – Portable X-Ray Fluorescence

Sub-tidal – The area below the mean low tidal zone

Supratidal – The area above the mean high water for spring tides

WA – Western Australia

CHAPTER 1: INTRODUCTION

The purpose of this thesis is to investigate and contextualise the intertidal archaeological landscape in relation to underwater sites located to the northern coast of Withnell Bay in Western Australia (WA). The study area is both an onshore and offshore site, that is situated to the west of the Burrup Peninsula (Murujuga), near the mining town of Karratha. The in situ archaeological sites located at Flying Foam Passage and the Cape Bruguieres Channel to the north of Murujuga demonstrated that it is possible for culturally modified materials to survive marine inundation in Australia (Benjamin et al. 2020; Benjamin et al. 2023; Wiseman et al. 2021). This resulted in the archaeological investigation of Withnell Bay, a large, shallow embayment consisting of hard bedrock, reef pavements, sandy mudflats, rocky outcrops and mangrove forests (Jones 2004:39). The geomorphological features of Withnell Bay would have provided an attractive landscape for past populations with access to raw materials, potable water and food resources (Figure 1) (Bird and Hallam 2006).

Figure 1: Context map of Withnell Bay, located to the west of the Burrup Peninsula, WA (map by L. Brooke).

This study utilised a desk-based and field-work approach to contextualise the archaeological and geomorphological characteristics of Withnell Bay, along with three intertidal surveys conducted across the northern coast focusing on the near-shore archaeology. The terrestrial environment was then compared against the underwater archaeology found by the Deep History of Sea Country project (DHSC), so that the assemblages can be understood as a continuum of the broader landscape.

On the 23rd of May 2022 a single underwater lithic artefact was identified, photographed, and left in situ by Professor Peter Veth, which prompted the DHSC team to return to Withnell Bay. In August 2023 four lithic artefacts were identified underwater and recovered for recording, however, it was unclear if the site was continuous across the landscape or if the artefacts were found in isolation. From the 20th till the 26th of September diving teams were deployed to survey the northern coast of Withnell Bay. Pedestrian surveys were used in this study to contextualise the intertidal landscape, the geomorphology and document archaeological sites found along the northern coast such as petroglyphs, grinding patches, lithic scatters, quarrying, shell middens and stone structures/features.

In 2019, the first confirmed subtidal sites in Australia were identified by the DHSC at Cape Bruguieres Channel (CBC) and Flying Foam Passage (FFP), the two sites are located towards the outer islands of the Dampier Archipelago. A broad scale iterative survey strategy was used by the DHSC including remote sensing techniques to map landscapes and identify potential underwater sites based on signatures from the terrestrial archaeological record that may extend underwater (Benjamin et al. 2020, 2023; Leach 2020:1; Wiseman et al. 2021). An adapted methodology from the DHSC has been used for this study, to contextualise the environmental and archaeological features of Withnell Bay. The Withnell Bay project and ongoing research of submerged cultural landscapes in Murujuga has been funded by the Australian Research Council (ARC) for the Discovery Early Career Research Award (DECRA) 2022 (Code: DE220100550) on behalf of Dr John McCarthy at Flinders University as a continuation of the DHSC project.

1.1 Research Questions

A combination of targeted fieldwork and pedestrian survey was used to characterise the northing shoreline of Withnell Bay and integrate the onshore intertidal environment with the subtidal archaeology

The following primary research question for this thesis is summarised as:

1. How can intertidal archaeological studies aid in contextualising submerged cultural landscapes and develop our understanding of onshore and offshore sites such as Withnell Bay?

The following corollary questions will aid in addressing the primary research question:

a. How do the intertidal and underwater archaeological assemblages at Withnell Bay compare?
b. To what extent do sites such as Withnell Bay enhance our understanding of maritime cultural landscapes in Australia?
c. What emphasis should be placed on interpreting submerged archaeological sites against the surrounding terrestrial record?

1.2 Research Aims and Objectives

To contextualise the northern coastline of Withnell Bay as an on shore and offshore site; the subtidal, intertidal and terrestrial archaeology has been investigated and analysed as a continuum. The survey of sub-tidal sites is often done in isolation, which disconnects the archaeological record from the entire of the landscape. This study aims to document the intertidal landscape of northern Withnell Bay as a holistic was of incorporating offshore sites with the broader landscape of the Burrup Peninsula. The following objectives will guide this study:

- Synthesise geomorphological and archaeological literature that has been published on Withnell Bay;
- Conduct pedestrian surveys across the northern coastline of Withnell Bay and record archaeological sites in the nearshore environment;
- Collate data that has been collected from targeted pedestrian surveys of the intertidal zone of Withnell Bay; and

- Provide recommendations for the future of submerged archaeological research applied at Withnell Bay.

1.3 Justification and Significance

The south and south-eastern sides of Withnell Bay have been subject of extensive research due to the expansion of the Karratha Gas Plant, resulting in archaeological salvage reports since the 1980s (Bird and Hallam 2006; Green 1982; Mulvaney 1989, 2005; Kirkby 1981; Turner 1981; Vinnicombe 1987:57). However, no published research focuses on the underwater archaeology of Withnell Bay and the intertidal zone of the northern coast. The contextualisation of Withnell Bay as an underwater site, and the methodology used in this study to survey and interpret the archaeological assemblages is significant to the future of underwater research in Australia. Withnell Bay may represent a third subtidal archaeological site and must be compared to the terrestrial analogue to aid in understanding the site pre- and post-sea level rise. Embayment's such as Withnell Bay are prospective sites which have the potential to preserve lithics, quarry sites and other rock structures which can endure marine inundation.

1.4 Ethics, Constraints and Limitations

The ethical approval for the DHSC/DECRA project in Murujuga is SBREC 7669 and extends until 31st of December 2025. All archaeological work in Murujuga is carried out in partnership with the Murujuga Aboriginal Corporation (MAC). All underwater survey work is covered under a Department of Planning, Lands and Heritage (DPLH) permit in WA, with no removal of onshore materials occurring during the Withnell Bay project. Any archaeological research conducted underwater research is constrained by the weather, tides and environmental conditions, this was factored into the survey plan by the DHSC/DECRA project. Limitations which were identified for this thesis project include:

- Access to cultural materials within a remote location;
- Access to comparable materials within the broader Murujuga landscape;

- Sedimentation within the eastern side of Withnell Bay limiting the visibility of artefacts which may date to periods of occupation in the Pleistocene and early-Holocene; and
- Non-disturbance surveying which limits access to buried artefacts.

1.5 Thesis Outline

The chapters outlined below will aim to answer the research questions stated in this thesis:

Chapter Two - Literature Review: Submerged Cultural Landscape Studies: is a review of submerged landscape archaeology as a discipline within Australia. It includes the study of sea-level rise, the geomorphology of the North-West (NW) shelf and archaeological sites which date to the Pleistocene and early-Holocene. This chapter also analyses intertidal and sub-tidal archaeological sites in Murujuga, as a regional analysis to contextualise Withnell Bay.

Chapter Three - Methodology:
describes the methods that have been used in this thesis to conduct a desk-based review of literature and fieldwork that focused on the northern coast of Withnell Bay.

Chapter Four – Contextualising Withnell Bay:
discusses the environmental, archaeological, cultural and industrial context of Withnell Bay.

Chapter Five - Survey Results:
describes the outcomes of the intertidal surveys which were conducted over three days at Withnell Bay. This chapter will report on archaeological sites and environmental observations and represent the findings in maps and figures.

Chapter Six - Archaeological Interpretation of Withnell Bay:
is the discussion section of this thesis which interprets Withnell Bay as an intertidal and sub-tidal site and compares the intertidal archaeological record with the

underwater lithics found by the DHSC team. The results will also be discussed in relation to sea-level rise since the Last Glacial Maximum and the future research potential of Withnell Bay.

Chapter Seven – Conclusion:

this section concludes the thesis and report on the outcomes of the research questions, aims and objectives.

CHAPTER 2: SUBMERGED CULTURAL LANDSCAPE STUDIES: GLOBAL AND AUSTRALIAN PERSPECTIVES

The study of submerged cultural landscapes is a multidisciplinary field of archaeology which investigates underwater sites that were once in-land areas that were occupied by past populations. The extent of sea-level rise has been linked to glacial and interglacial cycles which has been closely studied for over 40-years (Ford et al. 2020:5; Flatman 2013:3). Throughout the last one-million years, sea-levels have been approximately 40–130 m lower than present, with intermittent periods of sea-level high-stands dated to ~120 ka (Bailey and Flemming 2008:2153). Submerged archaeological sites have been located within near-shore coastal environments, intertidal and subtidal zones, lakes, riverbeds and caves which date to the late Pleistocene/early Holocene (Bailey et al. 2020:2; Flatman 2013:3). To provide contextualisation for submerged archaeological sites the broader terrestrial landscape and environmental observations must be considered.

Scientific publications which refer to the existence of submerged archaeological sites and lowered sea-levels date back to at least the early nineteenth century (Wickham-Jones 2018; Wyatt 1820). Clement Reid (1913) published '*Submerged Forests'* a which focused on palaeoecological and geological studies of inundated forests within England and suggested that the 'southern part of the North Sea would have been an alluvial flat'. This was seminal work stating that underwater sites and materials, such as stone features and circles, that date to antiquity or older could be found in inundated settings (Reid 1913:21). To understand the extent of human occupancy of the North Sea during lowered sea-levels, Reid, suggested that dredging areas of the Dogger Bank may aid in locating culturally modified materials (Reid 1913:21).

The use of bathymetric and topographical data continues to be used to locate submerged archaeological landscapes and map past land bridges, valleys, ridges and coastal plains that has now been drowned through rising sea-levels (Bailey 1983: Shackleton et al. 1984). In recent decades, increasingly high-resolution bathymetric data in conjunction with broadscale remote geophysical sensing techniques have been used to map underwater landscapes (Grant et al. 2014:52; Hearty 2007:2090). Bailey et al. (2020) identified four main factors that will assist the ongoing development of underwater cultural research:

1. The accumulation of prehistoric materials found in underwater settings, including the preservation of Ice Age mammals and organic materials that have survived in anaerobic conditions;
2. Bathymetric and sea-bed morphology data which aids in characterising potentially significant submerged landscapes;
3. The increased attention placed on understanding past sea-levels, climate proxies and utilising paleoenvironmental data to assist archaeological research; and
4. Offshore industrial and commercial expansion that aims to exploit the seabed and increased attention that relates to protecting underwater cultural heritage.

The submerged landscapes of Europe have been at the epicentre of underwater archaeological research since the early 20th century (Bailey et al. 2020:2). However, attention placed on underwater cultural sites has increased globally due to pressure from offshore developments across continental shelves and has resulted in a desire to increase the protection of the seabed, both ecologically and culturally (Nillson et al. 2020:78). The renewed interest in coastlines and coastal landscapes, supported by greater precision in remote sensing capabilities, mapping, geophysical modelling and underwater excavation techniques has been a key part of understanding global human dispersal (Bailey and Flemming 2008:2154).

In Australia, the dispersal of humans throughout the continental landmass of Sahul (Australia and New Guinea) can be understood through the study of submerged landscapes. Seminal work which focused on the underwater cultural landscapes of Northern Australia was conducted by Fleming in 1983. This study deployed a broad-scale diving survey of the Cootamundra Shoals, located 240 km north-west of Darwin, Australia (Masters and Flemming 1983:149). In 1967, acoustic surveys (echo sounder) were led by van Andel and Veevers in conjunction with the Australian Division of Nautical Mapping to map the geomorphological features of the seabed of NW Australia (Masters and Flemming 1983:152). In 1982, key survey objectives were to locate areas that would have sustained life as part of a productive environment that could be used by past populations. This resulted in over 230 diver surveys completed at depths ranging from 15–61 m which examined the fossilised banks of coral platforms within ancient valley systems along sandstone substrata. The

Cootamundra Shoals were a karstic valley system, which could have been an ancient route for human entry into Sahul. Despite the study being a formative example of both systematic mapping and surveying submerged landscapes in Australia, the study yielded no artefactual materials for further analysis (Leach 2020:252). The Cootamundra Shoals survey was the first instance of research which focused on locating offshore Aboriginal sites in Australia (Nutley 2014:261). However, this study was done in isolation with no contextualisation of the surrounding terrestrial landscapes of the Tiwi Islands to understand the extent of maritime cultural landscapes in NW of Australia.

In 1989 a submerged archaeological site was found across the lakebed of Lake Jasper, situated within the D'Entrecasteaux National Park to the southwest of WA. The site was surveyed from 1989–1990 which focused on both the nearshore environment of Lake Jasper and underwater (diving surveys). The team of divers and archaeologists were from the Maritime Archaeology Department of the Western Australian Museum (Dortch and Godfrey 1990:28). The underwater surveys successfully uncovered several hundred stone artefacts and tree stumps (*Xanthorrhoea preissii)* found at a depth of 3.9 to 10.3 m (Dortch and Godfrey1990:29). The stone artefacts found at Lake Jasper were considered to be in situ as Lake Jasper is within a 'poorly drained level sandplain' and is cut off from the nearby Donnelly River tributary, thus, high velocity water flows were deemed as an unlikely process that may have transported the submerged artefacts (Dortch and Godfrey 1990:30–31). Through radiocarbon dating of tree stumps at varying depths, Lake Jasper was estimated to have filled between 3700–4020 BP (Dortch 2002:119). The archaeological record of Lake Jasper represents a regional response to glacial eustatic-marine transgression within freshwater systems across the temperate southwest (Dortch 2002:10).

The Lake Jasper site was important for the application of surveys done in submerged settings; however, the lake site did not relate to global sea level rise and responses to marine transgression across the continental shelf of Australia. Comparatively, the study of the Cootamundra Shoals site, was focused solely on finding the first subtidal site in Australia. As more submerged archaeological sites are identified across the continental shelf of Australia and connected to onshore environments, sites can be contextualised as a part of the broader landscape and understood as a continuum, rather than isolated phenomenon.

2.1 Sea-Level Rise and Environmental Responses to the LGM

Sea levels have varied significantly due to glacial and interglacial cycles, inundating in-land areas which were once inhabited by ancient populations (Ford et al. 2020:5). In 1912, through the study of climate variability, a researcher from the University of Belgrade named Milutin Milankovitch, defined the term ‘Milankovitch Cycles’, the calculated cyclical mathematical variation of solar radiation over time. This was based on the earth’s elliptical variation and proximity to the sun; obliquity, or the tilt of the earth; and procession, the direction and rotation of the earth relative to the sun (Petrovic 2012; Spiegel et al. 2010). These cycles directly affect the variability of solar radiation that is absorbed within the atmosphere and correlates to global ice-volume changes over semi-regular intervals (each cycle spans approximately 41 ka) (Petrovic 2012). Underwater site formation processes, the preservation of artefacts, along with mapping the extent of continental landmasses must all understood in relation to Relative Sea Level (RSL) rise. Terminology such as eustatic and RSL rise emerged during the nineteenth century as scientific research debated the relationship between shoreline features and the regression of continental icesheets (Jamieson 1865).

The term eustatic sea level change can be described as the increase of evenly distributed water across a ‘rigid, non-rotating’ planet that does not consider gravitational and land surface responses (Mitrovica and Milne 2003; Shennan et al. 2015). The term ‘RSL change’ refers to ‘the elevation of the geoid (mean height of the sea-surface averaged over several decades) in relation to the solid surface of the earth’ (Shennan et al. 2015:6–7). As a result of glacial and interglacial periods the earth’s surface responds through the movement and rebound of continental landmasses, ocean and cryosphere which can be measured on both short-term (decades and centuries) and long-term scales (geological) (Spada 2017:153). Glacial Isostatic Adjustment (GIA) refers to the geophysical phenomena that occurs through the ‘waxing and waning’ of continental icesheets and includes responses such as Post Glacial Rebound (PGR) (Spada 2017:153). Scientific papers which discussed GIA theory published during the mid-1970’s (see Clark et al. 1978; Farrell and Clark

1976; Peltier 1974; Peltier and Andrews 1976; Peltier et al. 1978), discussed the extent of icesheets during glacial cycles which caused the ‘deformation of the solid earth which continued until isostatic equilibrium is reached’ (Peltier 2002:378; Milne et al. 2002:361). In Australia hydro-isostatic effects are small as the continent was situated far away from icesheets during the LGM (Yokoyama et al. 2001:282). The tectonic margins of Australia are stable which can be observed through relic shorelines of the last interglacial period (MIS 5e) with sea levels comparable to present day (Figure 2) (Yokoyama et al. 2001:282).

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Figure 2: Factors and responses to global and regional sea level rise. A) a simplified model of eustacy and glacio-isostacy. B) Multiple hypotheses of relative sea-level change and interactions based on Quaternary relative sea-level variation (Shennan 2015:7).

The analysis of paleo-sea level indicators aids in the reconstruction of past environments and measuring the range of glacial and interglacial sea-level fluctuations (Grant et al. 2014:52). The fixed indicators generally consist of geological, biological, and geomorphological factors that are consistently found within certain tidal elevations (Grant et al. 2014:52). Relational indicators refer to features that form due to sea-level differentiation in correspondence with the intertidal zone (beach-notches or wave-cut platforms). To test certain climate proxies, radiometric dating methods can be used to sample specimens of coral fossils, speleothems and microatolls (Grant et al. 2014:52). The determination of absolute sea-level indicators relies on whether the gathered information can be dated directly, whereas relative indicators provide broader information of sea-level sequences.

Marine isotopic data such as oxygen isotope ratios measured within calcium carbonate microfossils are used as a proxy to reconstruct past climates, which are particularly useful for describing the approximate extent of regional sea-levels (Figure 3) (Benjamin et al. 2020; Solihuddin et al. 2015; Grant et al. 2012). However, this method must be considered in relation to other variables such as tectonic deviation, regional sea-level anomalies, and subsidence (Lambeck and Nakada 1990:146; Lewis et al. 2013:119; Manne and Veth 2015:112).

Prior to the LGM, sea-levels were comparable to present during Marine Isotope Stage (MIS) 5e, with variable high-stands of 1 m to 4 m Above Present Sea-Level (APSL) (Hearty et al. 2007:2109). This was followed by a sharp increase at 120–118 ka as global sea-levels rose to 6–9 m APSL, subsequently sea-levels began to lower as the climate settled into the LGM low-stand at 20 ka (Hearty et al. 2007:2109). The LGM low-stand measured between 120 to 130 m BPSL within the Australasian region, which occurred between 20 ka to 7 ka (Lambeck and Nakada 1990; Lewis et al. 2013; Murray-Wallace et al. 2005). At approximately 8 ka during the mid-Holocene, sea-levels began to rise towards present levels as the climate gradually warmed (Lewis et al. 2013:129). The exposed landmass of NW Australia during the peak of the LGM would have sustained populations as a coastal landscape which was optimal for foraging, as sea levels transgressed these areas were drowned and populations would have retreated. The Dampier Archipelago would have been gradually inundated from approximately 8 ka onwards which changes how Aboriginal populations interacted with the landscape.

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Figure 3: WA regional sea-level curve (left), with a global sea-level curve (right) based on oxygen isotope data. The dark blue line represents the minimum age, whereas the light blue dotted-line represents a 95% confidence limit (Benjamin et al. 2020).

2.2 The North-West Shelf: Geology and Coastal Dynamics

To provide contextual background for sub-tidal and intertidal archaeological sites located in Murujuga, regional sea-level rise must be analysed, along with a broadscale review of the geology and coastal dynamics of the North-West Shelf (NWS). NWS is 2,500 km long and forms the continental margin of NW Australia (Wilson 2013:2). This coastal region consists of diverse biotic assemblages, marine habitats with distinctive patterns of inundation since the Pleistocene (Keep et al. 2007:151; Wilson 2013:2; Yeates et al. 1987). The NWS refers to the south-western Rowley Shelf (flanked by the Southern Indian Ocean), and the north-eastern Sahul Shelf (near the Timor Seas) (Figure 4). Sea-level fluctuations and tectonism were the primary controls that developed the NWS which was formed via two overlapping rim basins of the Tethyan Ocean and Gondwanaland that rifted during the Mesozoic (Keep et al. 2007:152; Wilson 2013:13). During the early-Cretaceous divergence of the tectonic plates caused Gondwana to rupture. This process formed the Indian and Australian landmasses, forming a submerged rift valley between the two regions, that filled with marine sediment (Keep et al. 2007:152; Wilson 2013:13).

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Figure 4: Map of the NWS, with Sahul Shelf to the north and the Rowley Shelf to the south (Wilson 2013:4).

As the seafloor spread, the two landmasses drifted apart with the eastern side of the rift-valley forming the western margin of Australia. This process created the West Australian Superbasin, the long, curved portion of the continental margin that connected the NWS and the Western Shelf (WS) or the Rottnest-Dirk Hartog Shelf (Keep et al. 2007:152; Wilson 2013:13). There was no clear delineation between the NWS and WS until the late-Tertiary, when the northwest of Australia was uplifted (Cape Range Peninsula) and resulted in a narrow separation of the continental shelves (Wilson 2013:13). Throughout the Quaternary as sea-levels receded, a large proportion of the continental shelf was exposed and connected the landmass of Australia to New Guinea in the north and Tasmania in the south (O'Connell et al. 2010:1). This greater landmass was known as Sahul and was colonised by humans during early migratory events from at least 50–70 ka (Crabtree et al. 2021:1303). During the mid-Holocene the land-bridge that connected the two regions was drowned as a result of post–glacial sea level rise (Wilson 2013:14). The geology and geomorphology of the NWS is characterised by two Pre-Cambrian blocks and four sedimentary basins that extend both onshore and offshore (Wilson 2013:17). The Pre-Cambrian blocks include the Kimberly Block (Kimberly Basin and King Leopold-Halls Creek Orogen) and the Pilbara Craton (Wilson 2013:16). The focus of this study is situated to the Pilbara Craton is 500,000 km^2 and consists of Pre-Cambrian granite-greenstone bedrock, with the northern margin overlain by the Carnarvon Basin (Figure 5).

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Figure 5: Tectonic units of NW Australia, the Pilbara Craton is outlined in red. The southern portion of the Pilbara Craton is covered in Neoarchean and Proterozoic rocks (Hickman 2023:3).

The offshore contemporary sedimentary basins of the NWS include the Bonaparte, Browse, Offshore Canning and North Carnarvon, which overlap, merge, or abut onto the Palaeozoic basins of the Australian landmass. The sedimentary basins of the NWS consist of volcanic and sedimentary rocks that range from the Cambrian until the Quaternary (Hickman 2023:17; Wilson 2013:17). The Dampier Archipelago is located within the Northern Carnarvon Basin, and the southwest major depocenters of the Barrow and Dampier Sub-Basins (Wilson 2013:19). The Dampier and Barrow sub-basins include onshore and offshore divisions, which include up to 15km of Mesozoic and Cenozoic sedimentary rock, that overlies the Palaeozoic sedimentary deposits (Gartrell et al. 2016; Longley et al. 2002; Marshall and Lang 2013). The geomorphology of the Carnarvon Basin region is characterised by low sandy shorelines and beaches, tidal flats, mangroves and beaches, along with Quaternary limestone outcrops and coral limestone benches that date to the late-Pleistocene (Wilson 2013:19). Post-LGM sea-level rise resulted in the area being interspersed with limestone islands, shoals and reefs (Wilson 2013:19).

2.3 Pleistocene Archaeology of Australia

The first entry of people into the Australian continent has been a contested subject that relates to global diffusion of humans out of Africa. The study of late-Pleistocene archaeology in Australia demonstrated that Aboriginal people occupied Australia long before sea-levels stabilised, as early archaeological theory suggested that the initial occupation of Australia was during the mid to late Holocene. This theory was disputed when Bowler et al. (1968, 1974) found artefacts, shell and charred/ochre-stained human remains within the Dry Lakes system of New South Wales (NSW), and confirmed that the occupation of Australia extends back to the Pleistocene (Allen and Holdaway 2009:45; Bowler et al. 1970:39; Bowler and Thorne 1976). The archaeological site of Lake Mungo is located on an eroded core of a shore dune which formed the terminal drainage system of the Willandra Billabong Creek (Bowler et al. 1970:42). Lake Mungo was dated between 25,000 to 32,000 years old, based on samples of shell and charcoal which was collected from various occupation horizons (Bowler et al. 1970:39). In later surveys, thermoluminescence dating of sand in-fill samples collected from grave sites returned an upper age range of 36–47 ka (Bowler and Price 1998:167). The date range proposed for the Lake Mungo site coincides with periods of lowered sea-levels at the height of the LGM between 18,000 to 30,000 years ago.

The age of the Lake Mungo site demonstrated that Australia was occupied during periods of lowered sea levels rather than the mid-to-late Holocene as originally believed. Sites which confirmed the Pleistocene occupancy of Australia were located by Roberts and Jones (1973, 1989) who conducted a systematic excavation of the Madjedbebe rockshelter (formally known as Malakunanja II) (Clarkson 2017:306; Roberts et al. 1990:156). The Madjedbebe rock-shelter located in Arnhem Land, Northern Territory (NT) returned an age range of 50–60 ka based on Thermoluminescence and Optically Stimulated Luminescence (OSL) dating methods (Clarkson 2017:306; Roberts et al. 1990:156). Clarkson et al. (2012, 2015) suggested the rock-shelter had an upper date range of 65 ka (with a 95.4% probability) (Clarkson et al. 2017:306). Clarkson et al. aimed to reinvigorate the way rock-shelters similar to Madjedbebe were excavated in order to provide a 'large-scale' spatially organised collection of artefactual materials, which explore behavioural responses of the first occupants within Australia (Wood 2017:172).

Archaeological sites that date to the Pleistocene, such as Madjedbebe and Lake Mungo, sparked interest in the movement and momentum of human dispersal across Sahul (Bird et al. 2016:11477). Theories of migration include (Bird et al. 2016:11477; Birdsell 1977; Bowdler 1996, Horton 1981; Tindale 1981):

- Birdsell (1977), who suggested that a rapid dispersal of humans occurred across the continent;
- Bowdler (1996) argued that dispersal patterns followed the coastline and initially avoided the arid interior; and
- Tindale and Horton (1981) advocated that humans followed riverine and woodland corridors towards coastal landscapes.

Bradshaw et al. (2019) proposed, that based on the dates of the Madjedbebe archaeological site and the increasing number of sites found around Australia which date to 47 ka, the window for humans entering Sahul ranges between an upper limit of 65–50 ka. Sites which date to the Pleistocene and relate to the first entry of humans into Australia were during periods of lowered sea levels, which would now be drowned landscapes on the continental shelf (Bradshaw et al. 2019:1057; Ditchfield et al. 2022:2).

The Carnarvon and Pilbara arid bioregions contain rock-shelters and open archaeological sites which provide examples of early life across the NW of Australia

(Veth et al. 2014:156). The term bioregion describes the broad scale environmental features of a landscape that shares common characteristics such as geology, geomorphology, climate and ecology. The interpretation of terrestrial archaeological sites found in coastal bioregions shows the changing patterns of human occupation and migration across Australia during the late Pleistocene and early Holocene.

In the NW of Australia, the archaeological site of Boodie Cave on Barrow Island contains archaeological materials which returned OSL dates related to the occupation of the cave from 50 ka onwards (Veth et al. 2017b:20). The stratified cultural deposits represent human behavioural responses to the dynamic maritime deserts of North-West Australia, as Boodie Cave throughout periods of lowered sea-levels would have been in an optimal position for marine foraging activities across the Pleistocene coastline (Veth et al. 2017b:20).

The archaeological assemblages found at Boodie Cave represent periods of intensive occupation (51.1 ka to 36.6 ka) and periods of abandonment (during the LGM) a ‘common phenomenon in desert lowlands of the Southern Hemisphere’ (Barberena et al. 2017; Veth et al. 2017b). The archaeological assemblage of the Boodie Cave site demonstrate that marine resources were relied upon for subsistence from 22.4–7.2 ka, which intensified as sea-levels increased and the coastline shifted during the Holocene. The site was then abandoned again from 6.8 ka and became relatively sterile from 2.5 ka onwards (Veth et al. 2017b:26).

To the north, the Pilbara coastline was approximately 160 km further offshore during the LGM and consisted of a broad coastal plain that was scattered with ridges and valleys, ephemeral water sources and mangrove forests (McDonald 2015:125; Wiseman et al. 2020:4). The Pilbara region hosts an assortment of rock art, stone tool production sites and inhabited rock-shelters that date to periods of lowered sea-levels during the Pleistocene and early-Holocene (McDonald et al. 2018:267; Straus 1990:255). The prominence of rock engravings across the highly weather resistant geology has preserved images of early Pleistocene landscapes and extinct fauna, suggesting that the occupation of the surrounding islands coincides with the arid Pilbara interior (50 ka) (Dortch et al. 2019:35). The coastal and insular landscapes of the Carnarvon and Pilbara bioregions contain some of the earliest examples of marine (shellfish) subsistence strategies outside of Africa and Southeast Asia. Thus, demonstrating varied cultural responses to environmental adaptation throughout the desert and coastal plains (Dortch et al. 2019:34).

2.4 Intertidal Archaeology of Murujuga

The intertidal zone is the areas which is delimitated by vertical tidal range and the horizontal gradient of foreshore area. Intertidal archaeology often provides the closest connection to submerged sites and can either represent culturally modified areas that were once part of an older terrestrial landscape that has become semi-submerged through rising sea-levels, or, closely related to marine lifeways even as sea-levels have stabilised (Smith 2017:1). The intertidal zone is key to understanding of the whole maritime cultural landscape, including the archaeological footprint, geomorphological history and taphonomy.

The NW Shelf of Australia has changed drastically as sea levels have risen post LGM. The case study for this thesis includes the broader landscape of the Dampier Archipelago which incrementally drowned since 9,000 cal BP and reached its present form by 6,000 cal BP (Ward and Veth 2017:377). Submerged cultural landscapes are described as ‘Sea Country’ or ‘Saltwater Country’ by Aboriginal people and include island, coastal and offshore regions, which can be viewed as a continuous landscape (Ward and Veth 2017:366). The shallow coastal water environments such as the intertidal zone, are dynamic and often affected by wave action, large tidal ranges and sedimentation fluxes (Missiaen et al. 2017:386). However, the intertidal zone provides an accessible land-sea transition with an array of submerged archaeological sites situated across continental shelves, often found within water up to 10 m (Missiaen et al. 2017:386).

2.4.1 Dolphin Island

In 2021 Dortch et al. reported on an intertidal archaeological site on Dolphin Island, within the Dampier Archipelago. The primary objective of this study was to record archaeological sites that pre-date marine inundation events positioned between Mean High Water (MHW) and Mean Low Water (MLW) (Dortch et al. 2021:511). A walk over-survey strategy was applied, which consisted of 1 m transect intervals and recorded sites and artefacts in situ using a Global Positioning System (GPS) transceiver (Dortch et al. 2021:511). Once the site was plotted, a drone was then deployed to capture landscape characteristics with high resolution imagery in order to create orthomosaics of the intertidal geomorphology.

Archaeological Results

The Dolphin Island intertidal site was found along a tidal mudflat of unconsolidated pebble and cobble sized rocks, along with outcropping of granophyre (a consistent geological characteristic found across the Dampier Archipelago). The site yielded 77 stone tool artefacts, including complete and incomplete broken flakes, single platform cores and multiplatform cores (Dortch et al. 2021:514). Although debitage was noticed across the site, the mud obscures smaller fragments and created a sample bias within the site. The maximum dimensions of the artefacts were between 5–12 centimetres (cm), along with a low flake to core ratio, which may relate to the survey targeting larger artefacts.

In order to link the lithic artefacts to potential areas of provenance, the chemical composition of five samples were analysed using a pXRF (Portable X-Ray Fluorescence). The samples included one artefact and one unmodified cobble located from both the intertidal survey site and the nearby Aboriginal stone quarry and one additional artefact from the quarry (Dortch et al. 2021:515). The intertidal artefact assemblages demonstrated a slight increase in calcium and strontium content which differed from the elemental composition of rocks found across the terrestrial boulder slope adjacent to the site (Dortch et al. 2021:516).

Site Interpretation

The pXRF results from the lithic assemblages determined that the artefacts of the intertidal site were not a result of the cobbles moving downwards across the naturally forming slope, and each artefact was rather ‘knapped from source materials found in their immediate vicinity’ (Dortch et al. 2021:516). The lithics were observed to have minimal abrasion which would suggest re-working of the artefacts from geomorphic processes and weathering. Dortch et al. also interpreted the site as a primary or secondary reduction zone due to the absence of primary cortex observed on majority of the recorded lithics, along with large cortical flakes being used as cores (Dortch et al. 2021:515).

The drone imagery shows that the tidal flat is flanked by Holocene beach dunes located to the upper side of the tidal range. The site is situated on a raised sand bank with evidence of drainage lines that occur from the eastern terrestrial surface (Dortch et al. 2021:517). During periods of increased rainfall, cobble and pebble sized rocks may have washed down the drainage lines and deposited within the sand bank. The discontinuous nature of the assemblage is indicative of a culturally modified site due to the heterogeneous concentration and distribution of lithics (Dortch et al. 2021:518). Dortch et al. suggested that the following theories may explain the formation of the site:

- Aboriginal populations visited the site post sea-level rise and raw materials were quarried to create tools to exploit the marine area for subsistence; or
- the deflation of a terrestrial landscape which discarded artefacts were then submerged into the intertidal zone.

The theories that were speculated by Dortch et al. require ongoing work to positively confirm the formation of the site and indicate that stone tools were created from raw materials found within the intertidal zone due to the limited time between high and low tide (Dortch et al. 2021:518). In 2019 O'Leary suggested that the alignment of the current beach represents a long-term formation, and the sandbank would unlikely become deflated due to changing wind patterns or currents experienced within the region (Dortch et al. 2021:519; O'Leary 2019).

2.4.2 Gidley Islands

In Leach et al. (2020, 2021) the intertidal and terrestrial landscapes of the North Gidley and Middle Gidley Islands in Murujuga were surveyed for archaeological sites which aid in contextualising the CBC assemblages from the DHSC project (Leach 2020:7; Leach et al. 2021:252). In Leach's (2020) a combination of aerial drone imagery and pedestrian surveys were deployed to map the area for prospective sites (Leach 2020:7). A total of six surveys were conducted that were either flagged by aerial imagery analysis, based on intertidal features that were flagged by colleagues (Benjamin and O'Leary 2018), or alternatively noted whilst out on fieldwork (Leach 2020:7).

Archaeological Results

The northwest of North Gidley Island yielded 32 scattered artefacts across 200m of the intertidal zone consisting of flakes, single and multiplatform cores and quarried granophyre (rhyodacite) (Figure 6) (Leach et al. 2021:257). (Leach et al. 2021:257). At approximately more than 10 m away from the high-water line and 200 m away from the intertidal lithic scatter, two weathered petroglyph engravings were recorded along the south of the shoreline. The northeast of North Gidley Island contained a deposit of beach rock along the shoreline extending 200m (Leach et al. 2021:58). Flaked stone tools were scattered across the beach rock, with some embedded within the matrix. Leach et al. speculated that where the beach rock is positioned (above the mean high tide), it was likely deposited during the mid-Holocene high stand (5–7 ka) (Leach et al. 2021:258). The outcrop of rhyodacite along the intertidal zone also displayed signs of quarrying, with an array of lithic artefacts.

The southwest of North Gidley Island comprised of weathered engravings near the intertidal zone, impacted by the proximity to salt-water. Burrup patches were identified across the peak of the outcrops and a higher frequency of engravings were noticed away from the waterline (Leach et al. 2021:258). Middle Gidley Island contained ‘ephemeral waterways, contiguous rhyodacite outcropping and a clay pan to the south’ (Leach et al. 2021:258). Leach recorded engravings, grinding patches and standing stones within mangrove and sloping terrain, located 100 m east of a seasonally variable waterway.

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100 M

100 M

Figure 6: North Gidley Island in situ artefacts and sites. Top left: photograph of artefacts scatters and quarries. Top Right: in situ flake with scale card. Bottom images: aerial maps comparing 2018 (left) and 2019 (right) mobile sands of the NW of North Gidley Islands (Leach et al. 2021:256).

Site Interpretation

Leach et al. (2021) determined that the sites were examples of a highly variable cultural landscape that supported subsistence practices, access to potable water before and after glacial transgression (Leach et al. 2021:260). The grinding patches showed polished surfaces attributable to seed milling, a high frequency of engravings and a large proportion of rhyodacite bearing cultural modification (Leach et al. 2021:260). Leach et al. (2021) argued that the stylistic nature of some petroglyphs and the weathering of certain sites suggests a landscape which dates from the terminal-Pleistocene onwards, despite challenges around absolute dating methods (Leach et al. 2021:261).

2.5 Sub-tidal Archaeology of Murujuga

In 2012 Dawson stated that ‘we are more likely to find evidence of maritime cultural interactions on the islands than underwater’ (Dawson 2012:19; Ward and Veth 2017:366). However, a renewed interest in submerged prehistory across the European continent occurred during the four-year programme that started in 2009 known as ‘Submerged Prehistoric Landscapes and Archaeology of Europe’s Continental Shelf (SPLASHCOS COST Action TD0902)’ (Benjamin and Hale 2012:237). The European subcontinent was exposed for most of human history and over 2,500 sites have been recorded in submerged settings (Flemming 2008:2153). In Australia the two first in situ submerged archaeological sites were found in 2019 and demonstrated that it is possible to identify sites across the Australian continental shelf (Figure 7) (Benjamin et al. 2020, 2023; Wiseman 2021). The CBC and FFP sites were the first sub-tidal ancient archaeological sites found on the continental shelf of Australia, decades after the first survey attempts that focused on the Cootamundra Shoals further north.

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Figure 7: Location map of the DHSC investigations of CBC and FFP sites to the north of the Dampier Archipelago (O’Leary 2023:2).

2.5.1 Cape Bruguieres Channel

In 2019 the DHSC project located over 269 lithic artefacts on the seabed of the Cape Bruguieres Channel (CBC), located between North Gidley and Middle Gidley Islands in Murujuga, WA. CBC is a 2–2.5 m gently sloping mid-Holocene ebb-tidal sand spit, characterised as a calcarenite terrace that situated above the springtide (Fig). The inter-island region is also dominated by igneous outcrops of granophyre (Benjamin et al. 2020:10; O'Leary 2023:1). The north-east entrance of the CBC consists of a large shallow reef and sand bank which boarders the Middle and North Gidley Islands, with the western entrance of the channel connected to Mermaid Sound (Figure 8) (O'Leary 2023:2). The primary archaeological site was located within a 2.5 km long and 125–150 m wide portion of the channel with a maximum depth of 2.2–2.4 m below MSL (O'Leary 2023:2). The tide-gauge on Legendre Island calculates that between the Mean High-Water Spring (MHWS) and the Mean Low-Water Spring (MLWS) the tidal range is 3.6m, meaning that the MHWS is +1.8 m and the MLWS is -1.8 m (Benjamin et al. 2020:10). Hydrodynamic data estimated that the channel ranges between being fully submerged at 2.4 m and partially exposed on the sill section across the middle of the channel at 0 to -1.4 m at low tide (Benjamin et al. 2020:11).

The channel floor represents an 'antecedent surface depression' which could have been a land surface that was once occupied at any time after the first arrival of people on the north-west coastal plain (Benjamin et al. 2020:11). Radiocarbon dates of marine shells that were collected from the surface of the aeolianite channel floor returned a date range of 44,700 to 26,600 cal BP (Benjamin et al. 2020:11). Shells which were collected from a marine calcarenite deposit on top of the aeolianite channel floor returned a radiocarbon-date range of 44,700 to 26,600 cal BP (Benjamin et al. 2020:11). The samples were also contaminated with modern carbon from endolithic marine boring organisms, which likely date to the past 7,000 years (Benjamin et al. 2020:11).

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Figure 8: An orthomosaic of the CBC archaeological site, the red dots represent sub-tidal lithics whereas the yellow represent intertidal lithics (Benjamin et al. 2020).

Archaeological Results

The CBC yielded two artefactual assemblages, the first consisted of 269 lithics that were divided into two in situ groups; intertidal (79) and sub-tidal (190) (Benjamin et al. 2020:12). The second assemblage consisted of 455 artefacts along with stone structures that were identified across the calcarenite terrace (Figure 9) (Benjamin et al. 2020:12). The artefacts were predominately made from rhyodacite (the bedrock geology of North Gidley and Bruguieres Island) and Andesite (bedrock geology of Lewis and Malus Island) (Benjamin et al. 2020:12). The sub-tidal lithics consisted of 'cores, core-tools, retouch flakes, mullers and two possible grinding stones' (Benjamin et al. 2020:14). The underwater samples were described as significantly larger specimens which had thick platforms and less evidence of knapping retouch.

The maximum length of the artefacts from both the underwater and onshore sites were measured and recorded in 2 cm increments, for comparative purposes between lithic assembles. The Bruguieres Terrace assemblage (onshore site) returned 449 lithics measuring between 0-12 cm, with the mode sample size measuring between 2-4 cm (228 artefacts). Comparatively, the Bruguieres Channel (intertidal and sub-tidal site) returned 210 artefacts which returned maximum lengths of 2–44 cm, with the mode sample size measuring 8–10 cm (52 artefacts) (Benjamin et al. 2022:14).

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Figure 9: Illustrations of the lithics (cores, flakes, scrapers) that were found at CBC, the map at the bottom includes depth profiles of the channel (Benjamin et al. 2020).

Site Interpretation

Benjamin et al. (2020) discussed the following hypotheses for the taphonomic and depositional history of the artefactual assemblages:

1. The site is in situ and is older than the onshore parallel;
2. The site has been re-deposited due to environmental processes such as tides, wave-action and/or cyclones; and
3. It is a lag deposit, the heavier materials were deposited on a dune feature that filled the channel at the termination of Holocene sea-level rise, with the smaller artefactual remains eroded by natural processes.

The sub-tidal or intertidal artefacts showed minimal signs of rounded/smoothed edges, that is generally consistent with rock that has interacted with water movement. It was noted that artefacts that were found over 50 m away from the shoreline showed minimal erosion and that acute edges remained on the culturally modified lithics and showed no signs of sorting which would suggest transport by high energy environmental factors (Benjamin et al. 2020:16). Artefacts of varying sizes were deposited at various depths, with larger artefacts distributed in sub-tidal and intertidal locations in comparison to onshore sites.

A proposed lag-deposit hypothesis suggests that the changing geomorphology as result of Holocene sea-level rise, may have caused the channel to fill with sediment and create an area that was able to be settled by people. Subsequently, this area would have been eroded by the rising sea, which transported the fine sediments and left the larger (artefactual) deposited material in situ (Benjamin et al. 2020:18). The lag-deposit hypothesis was supported by the presence of a Holocene beach complex, formed due to sea-level rise along the west coast of North Gidley Island and curving into the calcarenite terrace of CBC. The authors interpreted this ridge as having once extended along the west of North Gidley and Cape Bruguieres Islands, blocking the channel. It was later broken down through tidal movements and storm events which modified the channel and removed the finer sediments, leaving the artefacts in the current depositional environments (Benjamin et al. 2020:18). The lag-deposit hypothesis, however, was described as difficult due to the following factors:

1. No evidence of an accreted beach-ridge along the west coast of Cape Bruguieres Island that was captured by LiDAR DEM surveys;
2. No geomorphic evidence on the south of the channel that supports an erosion event; and
3. There is an ebb-tidal sand spit located on the south and west of the channel, with no accumulation of Holocene sediments, this is due to the strong currents which limits the amount (of sand-like sediments) which can be deposited within the channel.

The CBC site is located within a sheltered environment, protected from the harsh conditions of the open ocean such as wave, storm and cyclone modification. The authors document that the size and morphological features of the underwater lithics suggest that the cultural materials have not moved significantly and are deposited in situ on the Pleistocene land surface (Benjamin et al. 2020:21). The CBC site demonstrates an attractive calcarenite terrace landscape which would have been optimal for marine subsistence practices (Benjamin et al. 2020:21).

2.5.2 Flying Foam Passage

In 2019 the DHSC located a single lithic artefact in a seabed depression within Flying Foam Passage (FFP), between Dolphin Island and western Angel/Gidley Islands, in Murujuga, WA. The passage extends 15km long and 1.2km wide and is characterised by sloping pavements and coral reef flats (Benjamin et al. 2023:4). Multibeam and sidescan sonar methods were used to map the subsurface feature which revealed that the depression was an isolated feature and was not connected to a larger fluvial channel (Benjamin et al. 2023:6). The erosional features (notches) found within the depression represent an environmental structure that would have contained standing water, similar to a freshwater spring, during periods of lowered sea-levels in a terrestrial environment (Benjamin et al. 2020:22). The seabed depression or ‘wonky-hole’ (WH-1) measured 50 m wide and 80 m long within a limestone channel that measured 14 m depth BPSL (Wiseman et al. 2021:156). An analysis of the regional GIA suggests that the remnants of rivers, deltas or freshwater supplies were inundated at approximately 9,000 BP (or at 11 m BPSL) (Benjamin et al. 2023:6). In 2022 the DHSC returned to WH-1 in order to explore the feature in greater detail deploying a combination of multibeam, bathymetry, tidal analysis and diver surveys to establish the geomorphology and locate materials of potential cultural significance (Benjamin et al. 2023:3).

Archaeological Results

In 2019 a singular stone artefact was found within the depression, which was comparable to lithics found at Cape Bruguieres (Figure 10). It was deemed unlikely that stone tool was transported from terrestrial erosional surfaces to the submerged location due to weak velocity of currents and the distance to surrounding shorelines (Dolphin Island) (Benjamin et al. 2020:22). In 2022 a further four lithic artefacts were found at FFP including a broken rhyodacite (granophyre) flake, a complete gabbro flake, a large distal gabbro flake and a complete rhyodacite flake, substantiating the claims that the lithics found in WH-1 are within an in situ archaeological site (Benjamin et al. 2023:7–9).

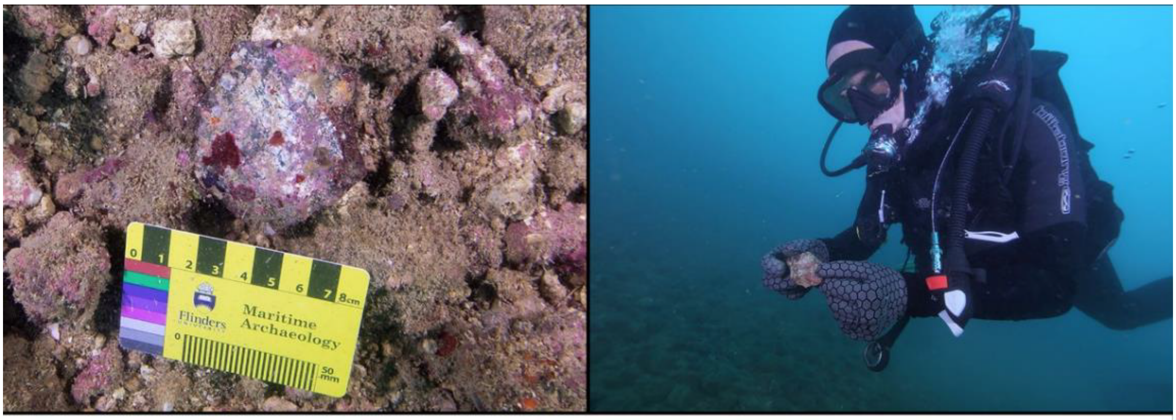

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Figure 10: The first lithic artefact found in 2019 from WH-1, photographs by H. Yoshida and C. Wiseman, artefact illustration by K. Jerbic (Benjamin et al. 2020:22).

Site Interpretation

The 2019 and 2022 surveys by the DHSC project set out to confirm that archaeological sites in Australia can extend beyond the intertidal zone and into submerged settings. The results of the CBC and FFP surveys demonstrate that artefactual remains can survive inundation across coastal environments within the Australian continent. The WH1 sea-bed depression represents a paleoenvironment that would have been rapidly filled by water during post-glacial sea-level rise. The morphology of the site, such as the erosional notches, are believed by the authors to have not been created by marine processes and estimate that the site dates to 9,000 cal BP and may in fact be much older (Benjamin et al. 2023:9).

2.6 Summary

Submerged cultural landscapes must be contextualised through the multidisciplinary study of the broader landscape in relation to geology, geomorphology, hydrology, climate, sea-level variation and terrestrial archaeological sites and assemblages. Archaeological research of terrestrial sites such as Lake Mungo, Madjedbebe, Boodie Cave and Murujuga Rock-shelter demonstrate that Australia has been occupied since the Pleistocene. However, the first entry of people into the greater landmass of Sahul and initial migration paths is still unknown, research must now focus on offshore environments to remedy this. Intertidal sites found on the coast of Dolphin Island and the insular regions of the Gidley islands demonstrate that past populations used the shallow intertidal zone to collect and forage for marine resources. Comparatively, the sub-tidal sites located at CBC and FFP demonstrate that during periods of lowered sea-levels archaeological materials were deposited across a terrestrial landscape that survived inundation.

The logistical demands of offshore archaeology often neglect connecting submerged cultural landscapes to the broader terrestrial context. The Dolphin Island site had no capacity to follow the archaeological trail beyond the intertidal zone, inversely, the sub-tidal site of FFP was disconnected from the surrounding insular regions. CBC contained lithic artefacts that extended sub-tidally and within the intertidal zone but showed distinct difference from the terrestrial analogue. This thesis endeavours to utilise intertidal archaeological surveys, completed in conjunction with diving surveys of the northern coast of Withnell Bay to contextualise the archaeology as a continuum which crosses both the onshore and offshore environments, which has not been done in current Australian research to date.

CHAPTER 3: METHODOLOGY

The intertidal zone, which is situated between MHW and MLW, is an easily accessible area that contains archaeological materials that either predate marine inundation or were part of a landscape that was used by populations since sea-level stabilisation (Benjamin et al. 2014; Dortch et al. 2021:509). In situ archaeological sites are more likely to be found within intertidal contexts in comparison to sub-tidal environments, which are often difficult to locate especially where the archaeological materials may be deposited beneath marine sediments (Peeters et al. 2020:152).

This study aimed to contextualise the nearshore environment of Withnell Bay in order to connect underwater sites to the broader terrestrial landscape. A desk-based theoretical approach in conjunction with systematic pedestrian surveys have been utilised to understand the archaeological and geomorphological characteristics of Withnell Bay. Withnell Bay represent a highly prospective intertidal archaeological site due to the proximity to raw materials (outcropping of bedrock) and the abundance of marine subsistence resources (mangroves, spinifex and shellfish) within a shallow protected embayment. The pedestrian surveys were completed in conjunction with diving surveys (conducted as part of the DHSC project) over three separate locations which were likely to preserve underwater archaeological sites. The following five-step system was deployed in this study to assess and interpret the coastal landscape:

1. Analyse literature that reports on archaeological sites and assemblages at Withnell Bay;
2. Conduct pedestrian surveys along the northern coast of Withnell Bay and record geomorphological features that may be prospective areas for underwater research;
3. Record any permanent, semi-permanent or mobile archaeological features that reside in the intertidal zone;
4. Embed geomorphological and archaeological data into spatial imagery that was collected for the DHSC project and create maps of intertidal archaeological sites; and

5. Contextualise the underwater and intertidal archaeology of Withnell Bay as a continuous site.

3.1 DHSC Withnell Bay Project and Discovering Underwater Archaeology

The Withnell Bay 2023 project, undertaken by the DHSC team from Flinders University aimed to utilise a similar methodology that was successful in past seasons at CBC and FFP (2016, 2017, 2019 and 2022) to locate a third submerged archaeological site (Benjamin et al. 2020; Benjamin et al. 2023; O'Leary 2023; Wiseman et al. 2021). The main objective of this study was to identify lithics that extend into the sub-tidal zone within Withnell Bay, utilise Remotely Operated Vehicles (ROV) for machine learning and to continue positive community engagement (Dr John McCarthy, pers. comm. 2023). In past studies, the DHSC (at CBC and FFP) a revised version of the Danish Model (see Benjamin 2010) was used to identify and interpret potential submerged archaeological sites. This method was based upon Anders Fischer's (1987, 1993 and 1995) model for the identification of Mesolithic and Neolithic archaeological sites (Appendix A).

3.1.1 Aerial Imagery

A DJI Mavic 2 Pro (no CPL filter) was deployed to collect high resolution imagery of the northern half of Withnell Bay along the shoreline (Phillipe Kermeen, pers. comm. 2023). The drone was deployed by Phillipe Kermeen over three missions at low tide in order to capture the extent of the intertidal zone in a tidally dominated embayment. The Mavic 2 Pro was equipped with a Hasselblad L1D-20c camera, a 1-inch CMOS sensor and an adjustable aperture with Omnidirectional sensing. The survey parameters were set in conjunction with survey size, resolution and battery life. The data was processed using Agisoft Metashape Professional Version 2.0.1 (build 15925) to create orthomosaics.

To characterise the offshore, intertidal and supratidal landscapes a drone was deployed on three separate occasions at low tide. The drone was flown over the coast at a height of 30 m, with 60% overlap, producing ortho-rectified photomosaics with a 0.87 cm/pixel resolution and a Digital Elevation Model (DEM) resolution of 2.67 cm/pixel. The drone flights were programmed and captured by Phillipe Kermeen, with data analysis and processing completed by Phillipe Kermeen and John McCarthy using AgiSoft Metashape and Drone Deploy Proprietary Photogrammetry Engine.

3.1.2 Diving Surveys

The DHSC 2023 diving surveys were conducted over six-days (20–26th of September 2023) and were completed at three different areas across the northern shoreline of Withnell Bay. An Underwater Information System (UWIS) was deployed and provided the location of each individual utilising ‘time-stamps’ to mark in situ locations of artefacts. The wireless transmitter was fitted to the air tank of each diver, along with three marker buoys were set in a triangular shape to mark the survey area (at set distances).

3.1.3 Lithic Analysis

Divers were deployed to locate sites and artefacts that would survive inundation such as stone structures and features and lithics. The artefacts were recorded and photographed in situ with a scale card and north arrow, with time stamps used to compare with GPS tracking data to record exact locations. The shape and size of lithics were used as indicators of rocks with potential signs of cultural modification, as smaller intricate details such as impact points and flake scarring are difficult to identify when lithics are covered in concretions. The lithics were then treated in a hydrochloric solution bath that dissolves any marine growth and were finally assessed by Dr Wendy Reynen (University of Western Australia).

3.2 Contextualisation and Desk-Based Study of Withnell Bay

A desk-based approach was used to contextualise Withnell Bay, as a wide variety of published literature discusses the archaeology, geology and geomorphology of bay to the south (Bird and Hallam 2006; Green 1982; Mulvaney 1989, 2005; Kirkby 1981; Turner 1981; Vinnicombe 1987:57). A review of publications, reports and publicly available data was used to assess the scope of archaeology and the geomorphology located at Withnell Bay, the following areas were the main focus points for further study:

- Environmental context;
- Cultural context;
- Archaeological context; and

- Industrial context.

3.3 Intertidal Pedestrian Surveys

Pedestrian surveys aimed to cover the intertidal zone across the northern coastal fringe of Withnell Bay and were completed over three days. The location of each survey started and ended at one of the three beaches (named A, B and C) which were accessible by boat (Figure 11). To record potential archaeological or geomorphological areas of interest a handheld GPS was used to mark locations, in conjunction with ContextCam (an Apple iPhone based location recording application). A small handheld digital camera (Olympus E-PL9) was used to take photographs (with a scale card and north arrow) and a notebook was used to record observations. Large geomorphological formations were captured through subsequent drone footage, that was re-deployed to collect spatial imagery of the area for post-processing analysis. The artefacts that were deemed culturally modified within the intertidal zone were recorded to create a systematic review of the landscape, and subsequently left in situ.

Figure 11: Contextual map of northern Withnell Bay intertidal surveys, including ortho-photomosaics (by P. Kermeen) with the five main accessible landscape features by boat or foot which dictated the direction of surveys (map by L. Brooke).

3.4 Post Processing and Interpretation

All data was sorted into surveys, date, location and artefact or site type. Maps were created in either ArcGIS Pro (version 3.2.0) or on QGIS (version 3.34.2 Prizren) to visualise spatial data.

CHAPTER 4: CONTEXTUALISING WITHNELL BAY

The DHSC team developed an iterative approach to locating areas with significant potential to preserve submerged cultural landscapes across the continental shelf of Australia. 'Multi-scalar' approaches were successful in identifying the CBC and FFP sites to the north of Murujuga which was based on predictive modelling (Benjamin et al. 2018; Veth et al. 2019; Wiseman et al. 2021). In the methodological approach discussed by Wiseman et al. (2021), it is imperative to understand the broader environmental landscape to shape archaeological research that is conducted underwater, involving the terrestrial record. The 'qualitative predictive model' is integral in understanding what archaeological materials in certain landscapes will survive marine inundation (Wiseman et al. 2021:155). This section will focus on understanding the broader geophysical characteristics of the landscape in conjunction with archaeological sites, cultural contexts and industrial implications that are relevant to Withnell Bay.

4.1 Environmental Context of Withnell Bay

4.1.1 Geomorphology

The Burrup Peninsula covers an area of 88 km^2 and extends past the town of Dampier, this area was once a separated island which was connected to the mainland via low-lying salt evaporators across the intertidal mudflats (Jones 2004:32). The hills are gabbro and dolerite 'barren rock piles' that are extremely weather resistant, whereas the low-lying terrain is situated under varying depths of seawater and forms modern embayments, straits and channels (Chen et al. 2020:232; Donaldson and Berry 2011:40; Semeniuk et al. 1982:102). The Burrup Peninsula and eastern islands are situated within the northwest Pilbara Craton, and ancient geological division of Archean granite-greenstone dated between 3.6 to 2.8 billion years old (Donaldson 2011:35; Hickman and Strong 2003:9). This formation consists of dark (iron and magnesium rich) coloured metamorphosed volcanic rocks created via supracrustal successions (Ramanaidou and Fonteneau 2019:674).

The overlying geology includes the Fortescue Group, a volcanic deposit of metamorphosed prehnite-pumpellyite which connects to the Archaean granite-greenstone at an angular-unconformity and is dated to 2.7 to 2.4 billion years old

(Hickman and Strong 2003:9). The Burrup Peninsula also includes the Dampier Granitoid Complex that extends over 100 km to Fortescue, with intrusions of the Gidley Granophyre dated to 2.77 billion years (Ramanaidou and Fonteneau 2019:273). Exposed granophyre (fine grained quartz and feldspar) is the dominate rock type that outcrops across the Burrup Peninsula with gabbro intrusions equivalent to basaltic lava (Donaldson 2011:35). Towards the outer islands of the archipelago the basaltic lava is the main bedrock with areas of exposed sedimentary rocks (Donaldson 2011:35).

The sedimentary compartments of the Pilbara coastal morphology consist of five units that describe the interface of the continental shelf, inner-shelf, sub-tidal and intertidal shore along with the backshore landform (Eliot et al. 2013:373). Withnell Bay is situated within the tertiary compartment that extends from West Intercourse Island to Dolphin Island Point, in this area the wide inner-shelf is characterised by a water depth of 20–50m between 28 to 80km away from the shoreline. The sub-tidal substrate is a mixture of hard bedrock, reefs and pavements, unconsolidated sediments and lime-sands (Eliot et al. 2013:373). The intertidal shoreline comprises of mudflats and tidal creeks, with small beaches on top of rocky-platforms and sandy beaches situated at the inlet of embayments such as Withnell Bay, Conzinc Bay and King Bay. The shoreline is fronted by tidal-flats and interspersed with mangrove forests, the supratidal zone and coastal hinterland consists of exposed granophyre bedrock that outcrops around the islands and peninsulas (Eliot et al. 2013:373).

The inundated ancient valley systems have experienced varying degrees of sedimentation from post-glacial sea-level rise, Withnell Bay and other large embayments such as King Bay include sand and mud substrata, comprise of diverse biotic assemblages. The bedrock chenier fringes to the northern and southern peripheries of Withnell Bay protect the sandy mudflat, with the shoreline of a supratidal sandbank located near the mangrove forest (Jones 2004:39). At the southern end of Withnell Bay there is a large delta that drains groundwater into the bay, which is visible at low tide, the intertidal mudflat is of Withnell Bay is scattered with deposits of gravel, cobble and boulder-sized rocks (Jones 2004:39).

4.1.2 Hydrology

Murujuga is characterised as an overlapping region of the tropical Indo-Pacific with warm to temperate oceanic zones (Osborne et al. 2000:74). The tides are macrotidal and are described as semi-diurnal, meaning two high and lows each day, the successive high and lows have slight height variations or diurnal inequality (Pearce et al. 2003:20). Maximum tidal ranges are between 5.1 m and 1.0 m depending on seasonality, with maximum values occurring during equinoxes and smallest values trending in winter solstices (Jones 2004:34). Circulatory patterns across the archipelago are characterised by large tidal variations and strong currents throughout the islands (Jones 2004:3434).

Wave patterns across the NWS are formed from winter easterly, tropical cyclone, or regional wind-generated swells, with more extreme swells in the winter months (Pearce et al. 2003:21). Comparatively, within the Dampier Archipelago, areas that are protected from the open Southern Indian Ocean are sheltered from harsh sea states through refraction and sea-floor friction which alters both wave height and direction (Pearce et al. 2003:24). At Withnell Bay, swells generally originate from the north and adhere to seasonal wind variations (south-westerly in summer and easterly in winter), with most wave heights south of Mermaid Sound measuring a median height of less than 0.6m (Pearce et al. 2003:24).

4.1.3 Climate

The Pilbara coast is an arid landscape with high evaporation rates (3200 mm per annum), the summers are generally hot and wet, whereas winter is generally warm and dry (Figure 12) (Jones 2004:32; Semeniuk 2013:27; Sudmeyer 2016:1). The majority of the Pilbara’s annual rainfall (approximately 300 mm) is experienced in summer, with tropical cyclones generating up to 25–34% of the total annual precipitation in singular events (Ramanaidou and Fonteneau 2019:673; Sudmeyer 2016:1). Maximum mean temperatures range between 36–37ºC in spring/summer and 28–29ºC in autumn/winter (Jones 2004:32; Loechel et al. 2011:6).

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Figure 12: Climate and rainfall patters on across the Pilbara (Ramanaidou and Fonteneau 2019:674).

4.1.4 Landscape Usage of the Burrup Peninsula

The geology, geomorphology, climate and hydrology of Withnell Bay and the surrounding Dampier Archipelago region are relevant factors that are key to interpreting any archaeological site. Archaeological evidence collected from rockshelters and open-air sites from tropical, desert and temperate regions across WA suggest that humans have occupied this space for over 50,000 years (Dortch et al. 2019:30). Since the Pleistocene, archaeological research suggests that Aboriginal People have settled and traversed from the desert to the coast (Dortch et al. 2019:30). Through rock art and the preservation of archaeological materials Murujuga demonstrates the transition of life between the Pleistocene and Holocene and the changing behaviour towards arid-maritime cultural landscapes (Dortch et al. 2019:35).

As the geomorphology, climate and coastlines have changed and regressed, resistant sites rock engravings, stone structures and lithic artefacts have been preserved, demonstrating how the region became increasingly reliant on maritime activities through marine inundation. At Withnell Bay it is important to consider the environmental characteristics of the landscape and how this both supported past populations along with the preservation archaeological sites. The outcrops of durable geological formations (such as granophyre) are easily accessible which makes Withnell Bay a desirable place to acquire raw materials for lithic production. The broader landscape of Murujuga was once a 'well-watered' refuge, with deep ridges incised into the landscape which were highly likely to contain vegetation and water (Berry 2018:34). Throughout the NW of Australia dietary responses to changing landscapes have been documented through shell middens. At approximately 4,000 years ago economic focus shifted from mangrove habitats to rocky shores and mudflats for subsistence activities (Clune and Harrison 2009; Dortch et al. 2019:35; Lorblanchet 1992). The coastline of Withnell Bay offers an abundance of rocky shorelines, intertidal mudflats and an expansive mangrove forest which could have supported past lifeways as sea-levels transgressed across the peninsula.

4.1.5 Post Glacial Sea Level Rise and Withnell Bay

The continental margin of Australia is relatively tectonically stable and was situated far from ice sheets during the height of the LGM which resulted in limited hydro and sedimentary isostacy (Lambeck and Nakada 1990:143; Lewis et al. 2013:115). The shallow nature of the continental shelf paired with stable environmental conditions makes Australia a positive location for the ongoing study of Pleistocene and Holocene responses to sea level rise. The bathymetry of the Dampier Archipelago is 'generally flat' and situated within a 30 m isobath that extends 25 km from the coast and is interspersed with deeper channels between the islands (Pearce et al. 2003:14).

Through the study of terrestrial sites such as Boodie Cave and Murujuga Rock-shelter the maritime desert landscapes of NW Australia are estimated to have been occupied since at least 51–46.2 ka and contain some of the earliest archaeological artefacts that relate to post glacial climate change outside of Africa and Southeast Asia (Dortch et al. 2019:34; Veth et al. 2017b:20). The Dampier Archipelago and Burrup Peninsula were once part of an inland mountain range of the terrestrial mainland of Australia. Approximately 21,000 years ago sea levels were -130 m BPSL and the coastline was 160 km away from its current location (McDonald 2015:126).

As the climate warmed and sea levels increased, the outer islands of the Dampier Archipelago such as Barrow Island and the Montebello Island would have made up the late Pleistocene coastal margin of NW Australia. The sea gradually transgressed across the Dampier Archipelago by 8–7 ka which created the interisland landscape, with Dampier Island (Burrup Peninsula) and Dolphin Island as some of last areas to become separated from the mainland of Australia by about 6 ka (Figure 13) (McDonald 2015:126).

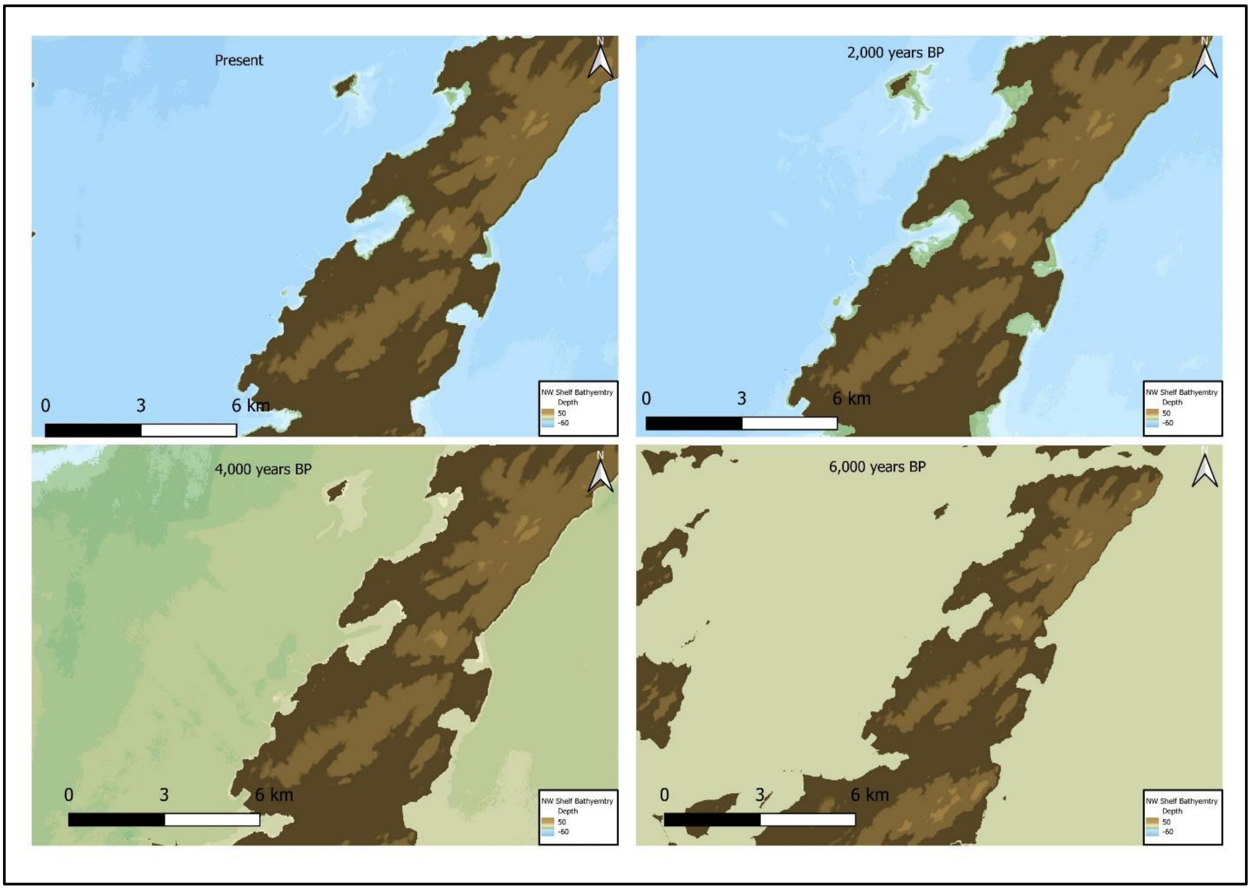

Figure 13: Withnell Bay during post-glacial marine transgression of the Dampier Archipelago, using NW Shelf Bathymetry (Lebrec et al. 2021) (map by L. Brooke).

Withnell Bay during the Pleistocene and early Holocene would have been a depression within the landscape or part of a valley system that made up part of the rocky hinterland that backed the Pleistocene coastal plain (Ward et al. 2013:224). It is hypothesised that the three major rivers (Nikol, Maitland and Fortescue) were not very active during the height of the LGM, and water was sourced from freshwater seepage points such as buried aquifers within landscape depressions similar to those such as modern embayments or channels between islands (Ward et al. 2013:224).

The Pleistocene coastline of NW Australia would have supported a broad spectrum of foraging and was a productive landscape for coastal populations. As the outer island became inaccessible from 8–4 ka, large channels and embayments formed with expansive mangrove forests that supported larger population groups that relied upon marine resources for subsistence (McDonald 2015:128). The late Holocene (4 ka onwards) transitioned from a reliance on mangrove and tidal flats to rocky landscapes within the intertidal zone after the mid-Holocene sea-level high stand (+1–2 m) (McDonald 2015:128). Withnell Bay would have been an attractive landscape for past Aboriginal populations throughout the Pleistocene and Holocene. During the peak of the LGM Withnell Bay may have been a prospective area for potable water and access to raw materials through outcrops of granophyre. As sea levels increased, the availability of natural resources transitioned from mangrove tidal flats to rocky shorelines, which is abundant across the northern landscape of Withnell Bay as it reached its modern configuration from approximately 6 ka onwards.

4.2 Archaeological Context of Withnell Bay

Murujuga represents a culturally and environmentally diverse landscape, with typical archaeological assemblages consisting of rockshelters, petroglyphs, grinding patches, lithic scatters and quarrying, shell middens and stone structures/features (standing stones, fish-traps). Primary archaeological investigations that focus the Burrup Peninsula and Withnell Bay include salvage reports for the extension of industry within the landscape (Kirkby 1981; Vinnicombe 1987). Other publications focus on interpretation of the terrestrial record, in relation to the intertidal and supratidal geomorphic zones (Bird and Hallam 2006; McDonald 2015; Mulvaney 1982, 2012; Turner 1981; Veth et al. 1994, 2018).

4.2.1 Petroglyphs

Murujuga contains the world's largest assortment of rock art engravings (estimated to be over 1 million) (Pillans and Fifield 2013:98; Veth and McDonald 2009:49). The petroglyphs of Murujuga were created by 'pounding or pecking' to remove parts of the exposed rock surfaces in order to carve images of anthropomorphs, marine, avian and terrestrial species, along with geometric/non-figurative motifs (McDonald 2015:130; Ramanaidou and Fonteneau 2019:677). Petroglyphs within Murujuga are often found on boulders that are situated near campsites or areas that are often revisited by the local Ngarda-Ngarli people (Bird and Hallam 2006:12). The observed stylistic changes noted across various engravings demonstrates highly adaptable social groups, identities and territorial boundaries that operated within a dynamic environmental landscape (Veth et al. 2018:287).

A common feature of rocks across the Pilbara is the orange-red colour that is caused by iron-oxidisation. Engravings are created when the surface layer of rock (often granophyre/gabbro) is removed up to a centimetre which exposes the often-pale light brown underside (Ramanaidou and Fonteneau 2019:671). It is extremely difficult to date petroglyphs, as relative methods rely on organic carbons trapped under the mineral coating of the exposed surface (Mulvaney 2012:1016; Veth et al. 2018:292). Thus, the dating methods primarily consist of the analysis of artistic styles that are comparable to other sites across the Pilbara, that creates a stylistic record within the region (Figure 14).

In 1982 Mulvaney aimed to address the issue of reliable rock art dating methods testing rock vanishes on 3,400 petroglyphs examples located to the south of Withnell Bay (Mulvaney 1982). Less than 12% of the total sample size contained this particular rock vanish and the study returned no viable age ranges (Mulvaney 1982; Mulvaney 2012:1016). Turner's (1981) conducted a study that focused on the spatial distribution of petroglyphs clusters at Withnell Bay. Turner suggested the following things were documented at Withnell Bay:

1. Bird and land animals are inversely related to marine motifs;
2. Engravings near the mangal areas have fewer marine motifs;
3. The Mangrove Creek, which is situated in-land, contradicts this, Turner suggests that this is due to the proximity to the ocean and its visibility; and
4. Areas of dense geometric patterns do not correlate with large habitation sites or the use of grinding patches.

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Figure 14: Stylistic changes in motifs through rock art engravings from the Pleistocene onwards. Examples show the changes from intricate patterns, large terrestrial and marine engravings as sea levels changed (Mulvaney 2015:762).

4.2.2 Stone Quarries

Quarries are located along seams, boulders and outcrops of rock that are used for the procurement of stone tools, where smaller fractured pieces of rock are removed and reworked (Bird and Hallam 2006:15). In Murujuga there is an abundance of fine-grained granophyre outcrops, along with varying inclusions of dolerite, gabbro and granite (Dortch 2002:37; Jones 2004:32; Vinnicombe 1987:16). Quarry sites are sites which are likely to survive inundation, and are identifiable by extraction pits, reduction zones and debris which can aid in identifying quarry sites along with negative flake scarring rock surfaced (Leach 2020: 25; Veth et al. 2019:18; Veth 2019:494).

Vinnicombe (1987) noted that in initial salvage surveys, quarries within Withnell Bay and the Burrup Peninsula region were located at select granophyre seams where 'countless blades were struck' and debitage was 'heaped around the rock source'. In locations where quarrying was evident on boulders situated on a steep incline, the refuse (such as fractures/snapped flakes) were found to be scattered downslope (Vinnicombe 1987:16). Smaller reduction sites were identified near campsites, where rocks could be carried to different locations and reduced into smaller flaked artefacts and cores (Vinnicombe 1987:16).

4.2.3 Stone Artefacts and Artefact Scatters

The Dampier Archipelago consists of various sites and scatters which range from individual artefacts to assortments of large complexes ranging in cultural materials. The distribution of archaeological sites across the Dampier Archipelago are determined by access to food, raw materials and potable water sources (Bird and Hallam 2006:12). Artefacts such as stone tools may be found in areas which likely supported habitation, such as campsites, food preparation sites, or the processing of raw materials. Comparatively, smaller lithic scatters or individual stone artefacts represent transient regions that may have been discarded along certain routes towards different locations (Bird and Hallam 2006:12).

Vinnicombe (1987) recorded 238 occupation sites across the southern Burrup Peninsula which were marked by the appearance of stone artefacts and shell refuse. The lithology of the stone artefacts was primarily granophyre, and small numbers of artefacts were quartzite (Vinnicombe 1987:64). The most common artefact type found within the Burrup Peninsula was flaked artefacts with edge alteration, that were commonly used for scraping and cutting, along with single and multiplatform cores (Vinnicombe 1987:64). In 1994 Veth et al. documented 498 sites across the Burrup Peninsula, with 20.9% of the assemblages listed as artefact scatters of varying densities. In WA the lithology of archaeological artefact assemblages is still poorly understood with lithics often grouped in broad geological locations such as ‘local and non-local’ (Ditchfield and Ward 2019:539).

In 2019 Ditchfield and Ward aimed to contextualise the petrographic data of artefacts across the Carnarvon and Pilbara coastal regions (Barrow Island) of NW-Australia. This study compared macroscopic, petrographic and geochemical signatures of discarded stone artefacts and demonstrated that the ‘local availability and accessibility’ argument is not ‘always simple’ and can place ‘complex influences on stone artefact assembles’ (Ditchfield and Ward 2019:354). The robust sampling of geological features across broad landscapes rather than just quarry sites may aid in understanding site and artefact distribution, as small cobbles are often used to create stone tools that may originate from alternative geologic locations (Ditchfield and Ward 2019:554).

4.2.4 Grinding Patches

Grinding stones and patches are commonly found in conjunction with lithic scatters (such as flakes or cores) or occupation areas which were utilised for the processing of food. The availability of grinding stones sheds light on diet (residue analysis), regional usewear along with associated social behaviours relating to gender roles of food processing in Aboriginal cultural practices (Reynen and Morse 2016:98; Webb 2007:115). Grinding stones can be defined as often large stone implements used to crush materials, that were either left at semi-permanent habitation sites or smaller variations that were more mobile and carried between sites (Australian Museum 2023). Comparatively, a grinding patch acts as a rock surface (pavement) that has been worn smooth for processing seeds or plants (Webb 2007:115).

Withnell Bay has over 142 documented grinding patches with residue evidence of silica gloss and roughened surfaces for reuse as milling stones (Turner 1981:42; Vinnicombe 1987:70). In Turner (1981) grinding patches which were located adjacent to clusters of engravings and were noted to have re-roughened surfaces that are characteristic of re-use over long periods of time (Bird and Hallam 2006:32). Bird and

Hallam (2006) suggest that grinding patches were utilised for the processing of spinifex seeds due to the sites proximity to areas used as potential camps nearby spinifex grasslands and reuse evidence on grinding tools (Fullagar and Wallis 2012:85).

4.2.5 Stone Structures

Stone structures or features are defined as 'intentionally placed or arranged stones that aid in our understanding of past human behaviour' (Beckett 2021:1). Beckett (2021) aimed to create a 'more nuanced understanding of the range of stone structures across Murujuga', stating that a broad typology of stone structures may be problematic in large scale projects or extensive landscapes (Appendix B) (Beckett 2021:49).

Standing stones commonly occur in ridgelines or vantage points and it is often difficult to determine whether standing stones are natural or cultural (Bird and Hallam 2006:12). The elongated rocks are upturned and wedged in between boulders, in other instances standing stones are more intricately placed on their own in more complex regions (Figure 15) (Bird and Hallam 2006:14). Standing stones represent both ceremonial and domestic purposes and vary across the Pilbara and Dampier Archipelago. Some standing stones represent areas which are prohibited to enter or act as markers for navigation, whereas *Thalu* sites which represent the local Ngarda-Ngarli traditional law (Bird and Hallam 2006:14). The *Thalu* sites also signify the areas in which the Yaburara people were slain in the 1868 Flying Foam Massacre (Mulvaney 2015:765). Fish traps are utilised in tidal inlets and consist of stone walls to trap or narrow certain openings in order to catch marine life (Beckett 2021:58; Vinnicombe 1987:70).

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Figure 15: Standing stones in Murujuga. A) schematic of standing stones, left to right, the first two are wedged and the last one is chocked. B) standing stones found across Murujuga (Beckett 2021:205).

4.2.6 Shell Middens

Shell middens are a ubiquitous part of coastal archaeology which aid in our understanding of past dietary reliance on marine resources and the importance that aquatic habitats had on human evolution. A shell midden can be defined as a site that contains deposits of shell interspersed with artefacts, bone, plants and other materials scattered within the matrix (Torben 2023:2). The distribution, age, sediment matrix and relationship to human culture are all fundamental parts in identifying the significance of shell middens in cultural landscapes (Torben 2023:3).

There is a clear research gap that aims to locate and understand shell middens that pre-date the Holocene as sea-levels settled at approximately 6,000 years ago, the visibility of shell middens often reflects that of modern coastlines (Bailey and Hardy 2021:2). The Rosemary Island shell midden located in an area that would have been

15 m lower than present sea levels and part of a transgressive coastline is one of the oldest known shell middens in the Dampier Region, dating to 9.5 ka (Bradshaw 1995; McDonald and Berry 2016; McDonald et al. 2018:267). Comparatively, to the south a singular *Syrinx* shell found wedged between two rocks found by Lorblanchet (1992) at Gum Tree Valley was dated to 22.5 ka and demonstrates that the item was transported throughout the Murujuga Ranges during Pleistocene and provides a maximum age for the region (McDonald et al. 2018:267).

At approximately 4,000 years ago a reliance on mangroves habitats declines, with foraging efforts focused on rocky near-shore environments, mudflats and sandy beach shellfish species (McDonald et al. 2018:267). Throughout Withnell Bay and the surrounding Burrup Peninsula shell refuse and shell deposits are found interspersed throughout the landscape in concentrated densities or smaller scatters that may represent travel routes or individual meals (Bird and Hallam 2006:12). The presence of shell, bone and plant remains often in relation with camp sites, other materials and hearths that are located near ‘shorelines, mangroves or mudflats’ (Bird and Hallam 2006:13; Vinnicombe 1987:23).

4.3 Cultural Context of Withnell Bay

The word Murujuga means ‘hip-bone sticking out’ and derives from the Ngarluma-Yaburara language. Murujuga includes the Burrup Peninsula and the 42 islands of the Dampier Archipelago. Murujuga is the traditional landscape of the Ngarda-Ngarli, which includes the Ngarluma, Yaburara, Mardudhunera, Wong-Goo-Tt-Oo and Yindjibarndi people, who have inhabited the coastal plain for over 50,000 years and share both a physical and spiritual connection to the landscape (Murujuga Aboriginal Corporation 2023). The Murujuga Aboriginal Corporation (MAC) was established in 2006 as a body corporate program of the Burrup and Maitland Industrial Estates Agreement (BMIEA) (Murujuga Aboriginal Corporation 2020).

BMIEA documented that all Native Title rights and interests for the Burrup Peninsula were submitted to the:

1. Ngarluma-Yindjibarndi (1994);
2. Yaburara-Mardudhunera (1996); and
3. Wong-Goo-Tt-Oo (1998).

MAC does receive any compensation for Native Title and is not solely restricted to this contractual agreement, also partnering with the WA Government and other industry groups. Murujuga was declared a National Park in 2013 and is jointly managed and operated with the Department of Biodiversity, Conservation and Attractions, the park consists of over 4,913 hectares, which is owned by MAC and leased back to the WA Government (Murujuga Aboriginal Corporation 2020). MAC has key interest in protecting Murujuga as a World Heritage Site for the landscapes considerable cultural and environmental significance both terrestrially and underwater.

4.4 Industrial Context of Withnell Bay

The Burrup Peninsula and Dampier Archipelago has had a profound increase in industrial expansion. Since colonisation, Murujuga and the surrounding coastal and desert environments have been transformed from the Traditional landscape of the Ngarda-Ngarli People into an industrial hub (Mulvaney 2015:766). Since the 1700s the Yaburara People encountered industries which utilised the area for pearling, whaling and maritime exploration, along with the expansion of sheep farming across the district since 1863 (Mulvaney 2015:766). The introduction of European colonisation affected Aboriginal populations throughout the Dampier Archipelago due to an influx of epidemics such as smallpox, and the displacement and massacre of the Yaburara people during the Flying Foam Massacre of 1868 (Mulvaney 2015:767).

In the 1960s iron ore ports and facilities were constructed across the Dampier Archipelago in conjunction with salt evaporation pens located throughout 105 km^2 of tidal mudflats between the Burrup Island and the mainland of Australia (Mulvaney 2015:766). In the late 1970s the NWS venture began offshore projects to create, build and expand areas to process oil and gas, which has increased industrial development across the Burrup Peninsula by 15 % (Pillans and Fifield 2013; Mulvaney 2011:21). The offshore deposits of oil and gas were connected to the KGP at Withnell Bay via a 135km long subsea pipeline located to the south of Withnell Bay and is described as ‘the most advanced, integrated gas production system in the world’ (Jenkin 2022:13). The KGP produces liquid natural gas (LNG), domestic gas, condensate and liquified petroleum gas (LPG), which is managed by Woodside Energy Ltd. KGP operates through the Withnell Bay terminal, with gas received from two trunklines located approximately 130km offshore (Figure 16) (Jenkin 2022:13).

The plant has exported over 5,000 LNG, LPG, gas and oil cargoes internationally, with remaining supplies transported to southern WA (Chevron 2023; Jenkin 2022:13). The KGP terminal located at the Withnell Bay has been operational since 1989, with initial archaeological surveys focused on the salvage of terrestrial archaeological sites that may be impacted due to industrial expansion. However, in recent studies industrial emissions have been monitored to determine the long term affect it may have on ancient rock engravings (see Bednarik 2002; Pillans and Fifield 2013; Ramanaidou and Fonteneau 2019). Samples were collected from petroglyphs situated near the LNG KGP and were analysed to assess how natural erosion rates of engravings differ in comparison to modern erosion rates (post-industry) (Pillans and Fifield 2013:98). Pillans and Fifield (2013) conducted cosmogenic nuclide measurements to assess the variable rock surfaces and concluded that low rates of erosion are commonly found on silcrete/quartzite lithologies, within areas that received <400mm rain per annum.

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Figure 16: Aerial image of the Karratha Gas Plant at Withnell Bay (Woodside Energy 2023).

Comparatively, high rates of erosion are found on engravings that are on sloped surfaces, covered in soil/sediment, near streams, receive >400mm rainfall per annum and are on less resistant lithologies (Pillans and Fifield 2013:105). The Burrup Peninsula samples measured an erosion rate of 0.15mm per 1000 years, with some engravings measuring up to 10mm thick (Pillans and Fifield 2013:105). This study concluded that petroglyphs in Murujuga could date upwards of 60,000 years on the highly resistant granophyre bedrock. Secondly, this created a baseline to compare future measurements, in an attempt to monitor the effect of erosion rates within the archipelago and aid in the protection of culturally significant sites.

CHAPTER 5: SURVEY RESULTS

The three pedestrian surveys were conducted along the intertidal zone of northern Withnell Bay on the 20th, 22nd and 26th of September 2023. This area was chosen as a contextualisation study of the terrestrial archaeology and geomorphology, which can be compared with underwater sites identified by the DHSC/DECRA project. A total of 70 sites (engraving panels, grinding patches, quarrying and standing stones) and artefact scatters (cores and lithics) were found in intertidal and nearshore areas along the northern coast. This included single platform cores *(n = 2),* multiplatform platform cores (*n = 5)*, complete and broken flakes (*n = 31)*, engravings (*n = 20)*, quarrying on both mobile and immoveable stones (*n = 11)* and a standing stone (*n = 1)* (Figure 17)*.*

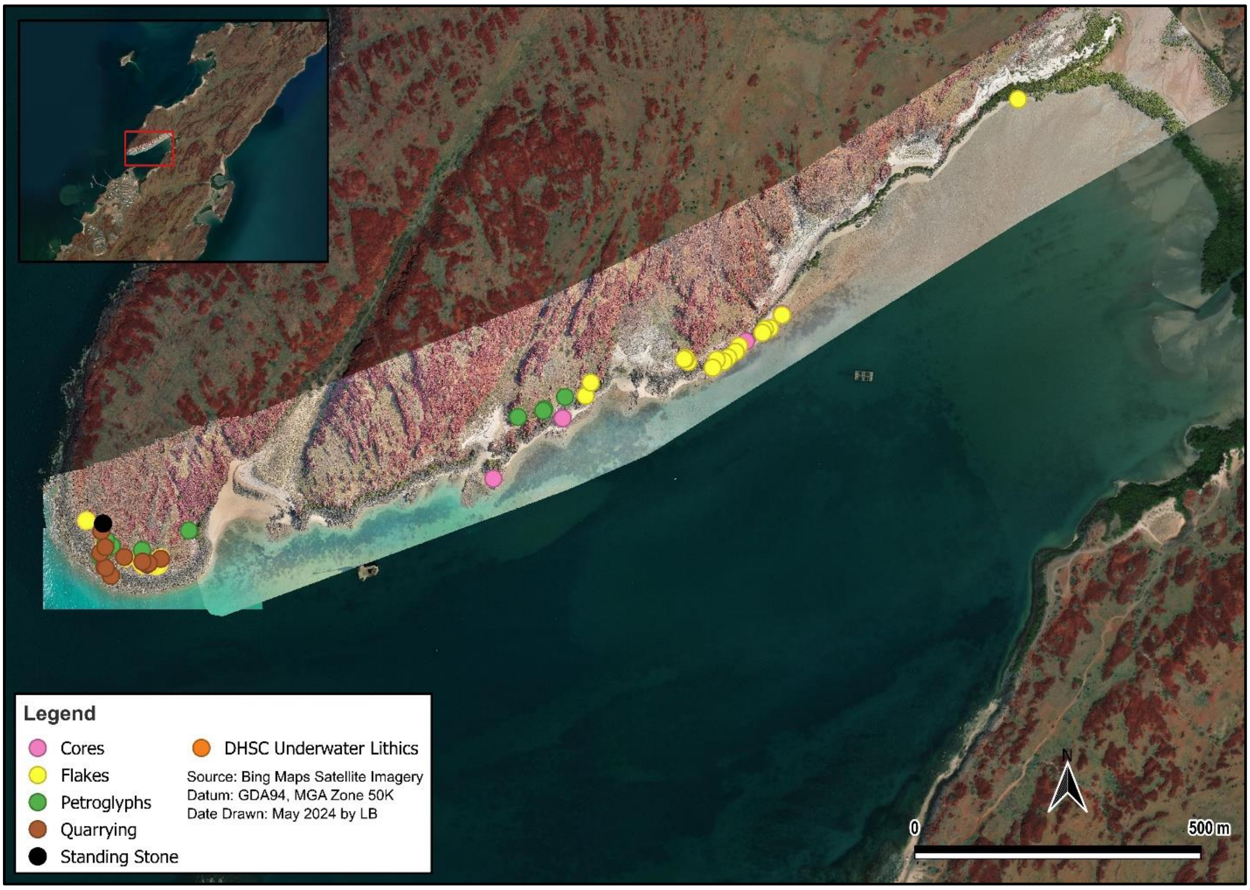

Figure 17: Total intertidal archaeological sites recorded over the three pedestrian surveys (map by L. Brooke).

The northern coastline of Withnell Bay is dominated by granophyre outcrops that extended throughout terrestrial and marine landscapes and a large mangrove forest to the east, with smaller intermittent collections of mangroves situated between rocky outcrops and along the fringe of beaches and coves. Small clasts of cobble sized rocks and large deposits of beach-rock (consolidated layers of shell and rocks that become cemented together with limestone/sandstone) are found across the four coves. The northern coastline of Withnell Bay is surrounded by steep hills of large granophyre boulders, covered in red desert patina from the iron rich soils and were frequently interspersed with spinifex (*Spinifex sericeus*). The dominate sediment type towards the western (seaward) side consisted of coarse sand with shell detritus, and a fine sandy silt towards the east near the mangroves and seasonal delta.

Lebrec et al. (2021) compiled a regional high resolution bathymetric dataset of NW Australia from Cape Range to the Dampier Archipelagos, based on this dataset the underwater morphology of Withnell Bay includes a wide, flat area which extends around the bay in a ‘U’ shape and follows a similar elevation to the terrestrial bedrock. The areas which resemble the same elevation as the terrestrial bedrock can be flagged as areas for future diving surveys, as the extent of the outcropping within the bay is unknown. To the east, the bay has likely become filled with sediment accumulated from both tidal movement and the deposit of silt from the small delta. In the centre of Withnell Bay a deep channel runs parallel to the headlands to the north and south. Tidal movement has likely carved out this channel as it connects with the mouth of the embayment (Figure 18).

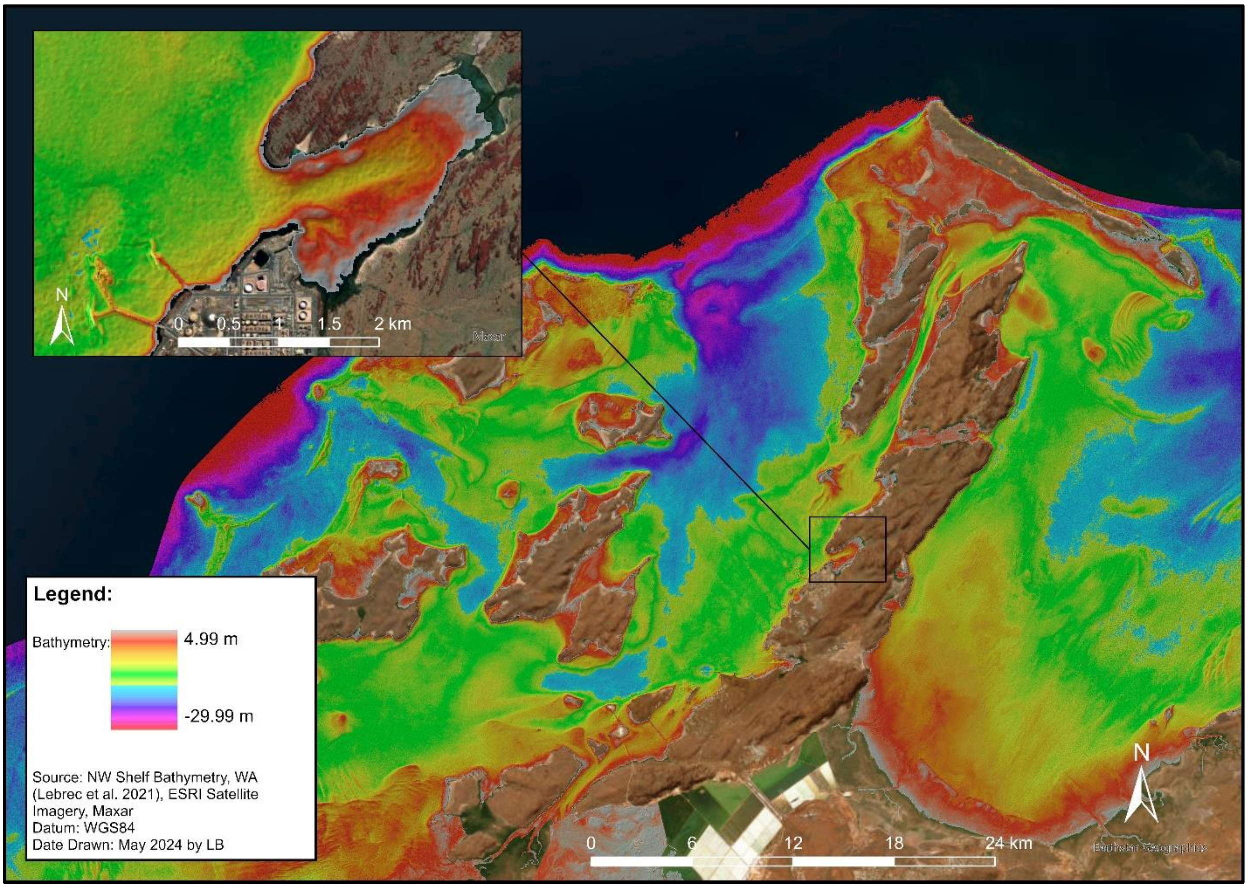

Figure 18: NW Shelf Bathymetry (Lebrec et al. 2021) depicting the sea-floor morphology of Withnell Bay with hill-shade applied (map by L. Brooke).

5.1 Survey 1: Beach A to Beach C

The first intertidal survey was conducted on the 20th of September 2023 between Beach A and C and occurred at the same time diving surveys investigated underwater for archaeological sites (Figure 19). This area consists of a long stretch of weathered granophyre boulders that are submerged by water at high tide. The walking transects followed a northeast bearing from Beach A and concluded at Beach C.

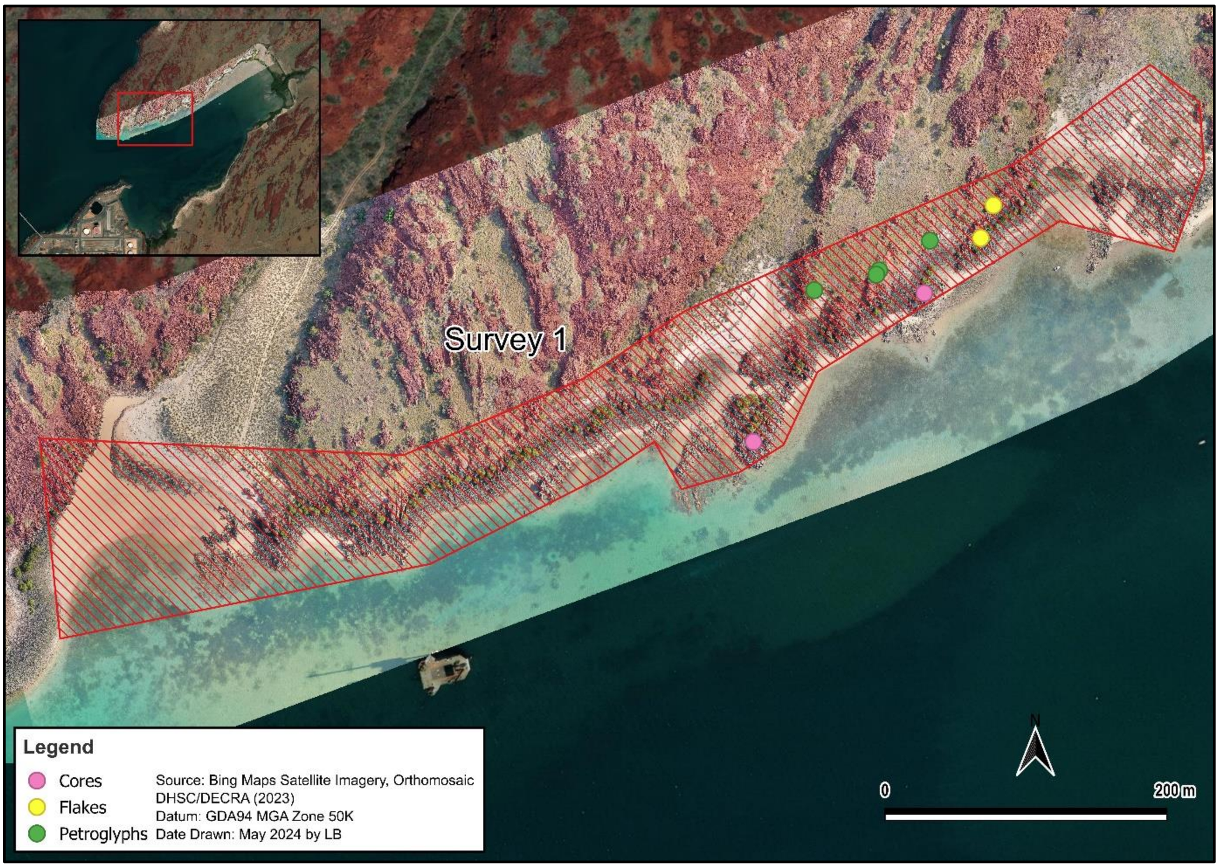

Figure 19: Total survey coverage of intertidal survey one from Beach A to Beach C (map by L. Brooke).

The intertidal landscape of survey one consists of mangroves, dark-grey granophyre outcrops that extend underwater with exposed rock that is not submerged at high tide covered in a red hue (Figure 20). The sand matrix was coarse-grained including shell detritus, along with cobble and pebble sized rocks. Towards the supratidal zone the beaches were covered in consolidated beach-rock. A small cove that is situated between Beach A and Beach B was covered with a thick layer of shell which overlayed the sand sediment, due to the quantity of shell located within this area, it was deemed to be naturally occurring rather than an anthropogenic shell midden (Dr Wendy Reynen, pers. comm. 2023).

Figure 20: Landscape context shot of the northern coastline of Withnell Bay (photo by L. Brooke)

5.1.1 Archaeological Sites and Artefacts

Located at the beginning of intertidal survey one a collection of five engravings were found across multiple panels (Figure 21). The images consisted of an anthropomorphic figure, marine species (turtle), avian species (emu), concentric bands and an unidentified pattern ‘pecked’ into the surface of a rock.

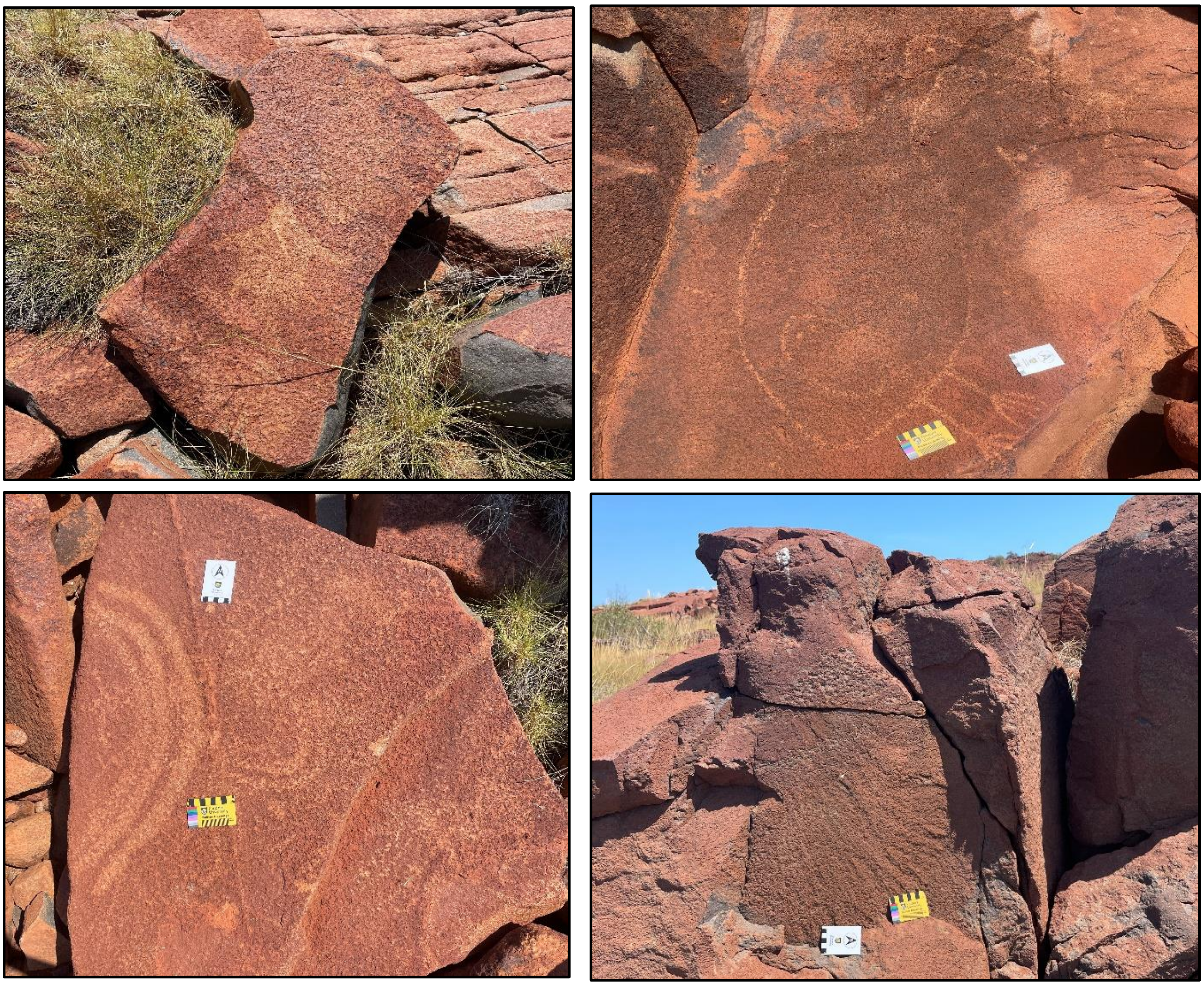

Figure 21: Survey one petroglyph panels, a panel of three engravings top left: turtle figure, top right: coastal bird with an egg and a faded sting-ray near the beak, bottom left: concentric bands and bottom right: triangle ‘pecked’ patterns (photos by L. Brooke).

Four lithic artefacts were found within small rock pools and wedged between larger rocks across the intertidal landscape and recorded in situ (Figure 22). The assemblage consisted of one multidirectional core, a single platform core and two flaked artefacts (Appendix C).

Figure 22: Lithic artefacts in the intertidal zone during survey one (photos by L. Brooke).

5.2 Survey 2: Beach C to Mangrove Forest

The second intertidal survey was conducted between Beach C and the Mangrove Inlet situated to the east, the survey began at the inlet and tracked on a northwest bearing (Figure 23). This survey was completed at low tide, in order to access the area around the mangroves which would often become submerged as the tide changed. The intertidal environment proximal to the mangroves is characterised by fine sand and silt sediment types interspersed with shell fragments. Along the intertidal landscape granophyre cobbles showed signs of erosion, such as smoothed surfaces and edges from being frequently submerged and transported from tidal and current movement.

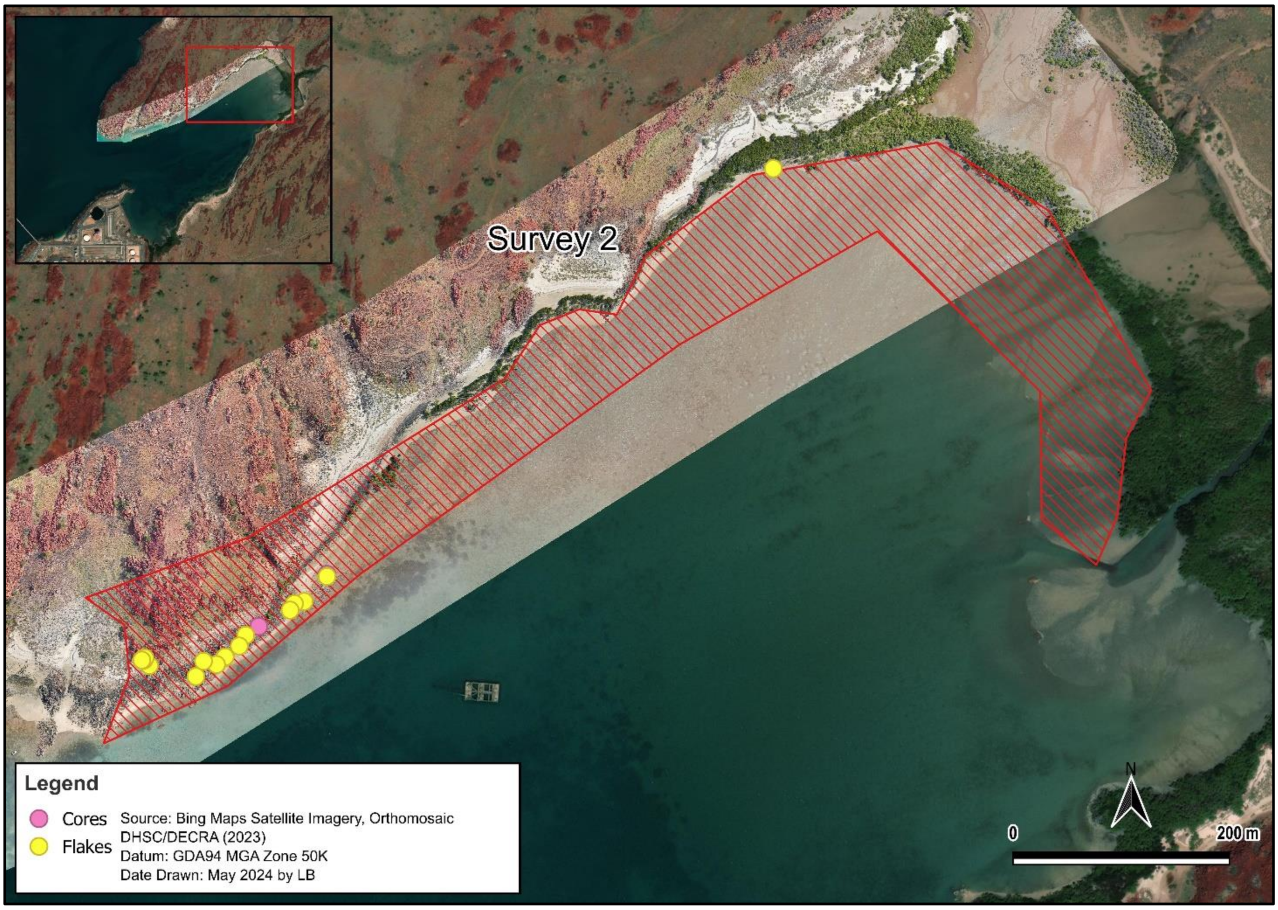

Figure 23: Total survey coverage for intertidal survey two, from Beach C to Mangrove Forest (map by L. Brooke).

The geomorphology changed as the intertidal zone shifted from mangrove dominated shorelines to exposed outcrops of granophyre which extended sub-tidally (Figure 24). The beaches along this survey consisted of course-grain sand sediments with crushed shell. Towards the supratidal zone a large, concreted limestone terrace with rocks, shell and other detritus likely represents a relic beach rock features from when sea-levels were higher than present (during MIS 5e). As the geomorphology shifted from mangrove environments to exposed rocky terrain, lithic artefacts were identified more frequently.

Figure 24: Context shots of survey two geomorphology, including beach rock likely dating to MIS 5e – during periods increased sea-levels (photos by L. Brooke).

5.2.1 Archaeological Sites and Artefacts

Archaeological materials located during intertidal survey two consisted of 19 lithic artefacts that ranged from multiplatform cores, single platform cores and flaked stone artefacts. Situated to the east a single flaked lithic artefact was found within a large deposit of cobbles and was covered in a fine-grained sand approximately 5 m away from the mangrove trees (Figure 25). The flaked artefact was the only lithic that was identified across this section of survey two, due to the large amounts of sediment deposited around the mangrove trees it was difficult to identify culturally modified materials.

Figure 25: Lithic artefact near the mangrove forest to the east of Withnell Bay (photos by L. Brooke).

The second section of survey two was conducted across a long stretch of open beach that consisted of boulder sized rocks interspersed along the coastline (Figure 26). A total of three multiplatform cores, one single platform core and fourteen flaked stone artefacts were found scattered along beaches, rocky outcrops and towards the supratidal zone (Appendix D).

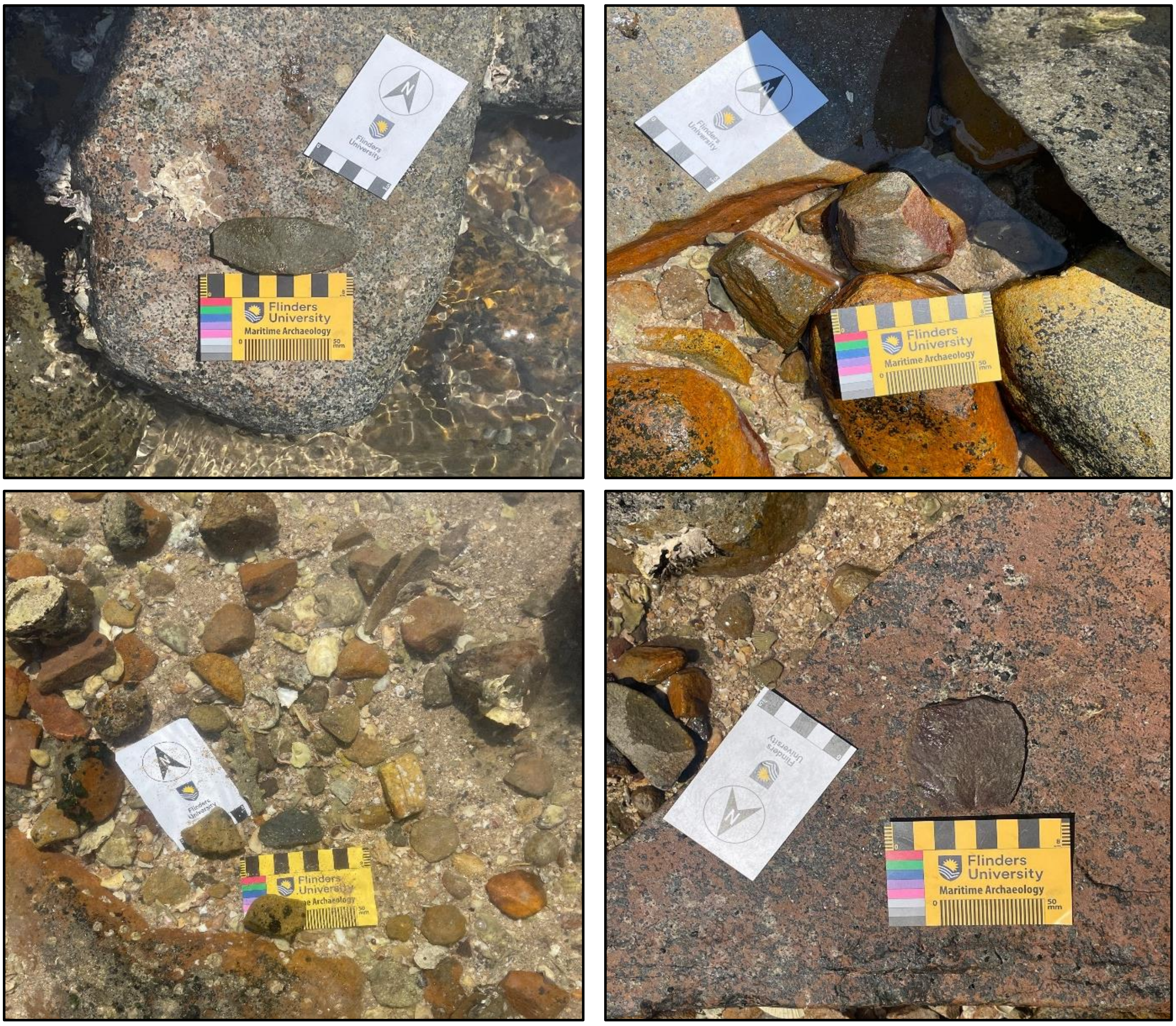

Figure 26: Survey two lithic artefacts in the intertidal zone (photos by L. Brooke).

A small rock-shelter/cave was located above the supratidal and contained an assortment of large, flaked stone artefacts with signs of retouch and debitage scattered around the site (Figure 27).

Figure 27: Lithic artefacts near a small rock-shelter/cave, the cave was too small to entre, however, lithics were scattered around the site with debitage in the shell/sand matrix (photos by L. Brooke).

5.3 Survey 3: Northwest Headland (NW-H)

the third Intertidal survey was conducted at the southern-end of the NW-Headland at the intersection of Withnell Bay and Mermaid Sound (Figure 28). The NW-Headland site was chosen as a prospective area for diving surveys. Walking transects were completed across the headland, aiming to stay as close to the intertidal zone as possible. However, a small overlap of the terrestrial environment was necessary in order to contextualise the broader landscape against the underwater environment. The area consisted of granophyre outcrops positioned along the steep hills and plateaus interspersed with spinifex, soil, and shell sediments.

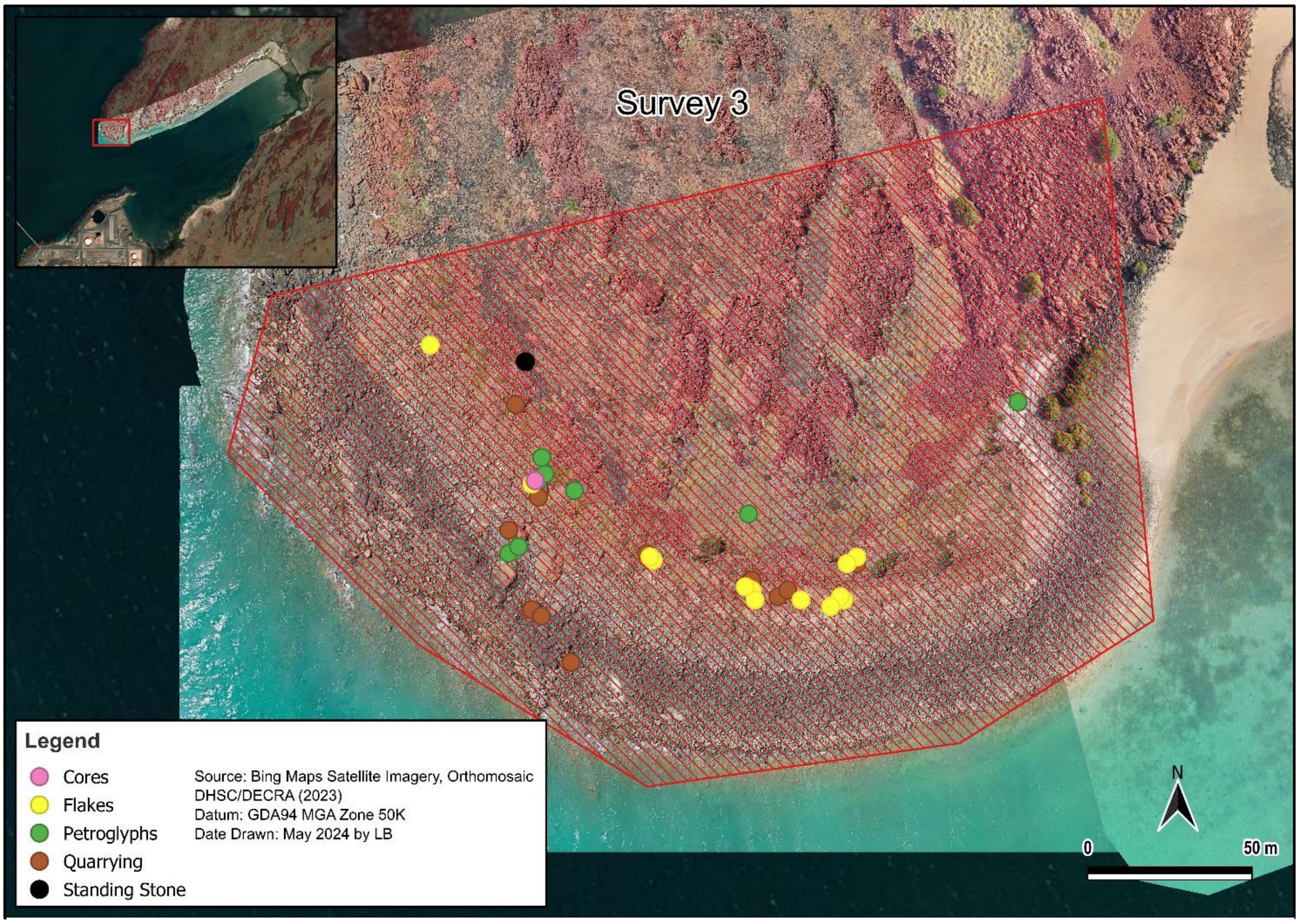

Figure 28: Total survey coverage for intertidal survey three, from the NW-H to Beach A (map by L. Brooke).

5.3.1 Archaeological Sites and Artefacts

The NW-Headland sites consist of a standing stone, quarries, engravings and artefact scatters which range in density (Appendix E). A multiplatform core identified within the intertidal zone, along with complete and broken flaked stone artefacts that range in size (Figure 29).

Figure 29: Lithic artefacts scattered across the NW-H occurred in dense patches and ranged in size and morphology (photos by L. Brooke).

A standing stone was situated on a granophyre ridge to the south-west, along with seven engravings which were located on numerous panels across the headland (Figure 30). The engravings included highly weathered lines, concentric bands, anthropomorphic features, and avian track marks. Rocks with negative flake scars demonstrate that quarrying occurred at the NW-Headland which is evident across large rhyodacite boulders and smaller portable stones.

Figure 30: A standing stone was located along a ridge to the south-west of the NW-H (photos by L. Brooke).

Quarrying occurred throughout the intertidal and terrestrial environment of the NW-H, however, it became less frequent and highly weathered as the survey tracked closer to the waterline (Figure 31). The NW-Headland site was the most prospective environment for the continuation of archaeology which extended underwater and was flagged for further surveying.

Figure 31: Quarrying of terrestrial and intertidal rock (photos by L. Brooke).

5.4 DHSC Survey of Northern Withnell Bay

Two fieldwork seasons were carried out at Withnell Bay in 2022 and 2023, with the first lithic artefact identified underwater during a recreational kayak trip by Professor Peter Veth (University of Western Australia), the lithic was photographed and left in situ (Figure 32).

Figure 32: A submerged stone tool noticed by Professor Peter Veth of the University of Western Australia during a recreational kayak along the north shore of Withnell Bay on the 23rd of May 2022 (photo by P. Veth).

This prompted the DHSC team from Flinders University to return to Withnell Bay and conduct further surveys on the 25th and 26th of August 2023 (Figure 33). During this survey, a further four lithic artefacts were recovered, but it was unclear whether the lithics were in situ or deposited through environmental processes or represented a continuous underwater archaeological site rather than isolated artefacts (Figure 34).

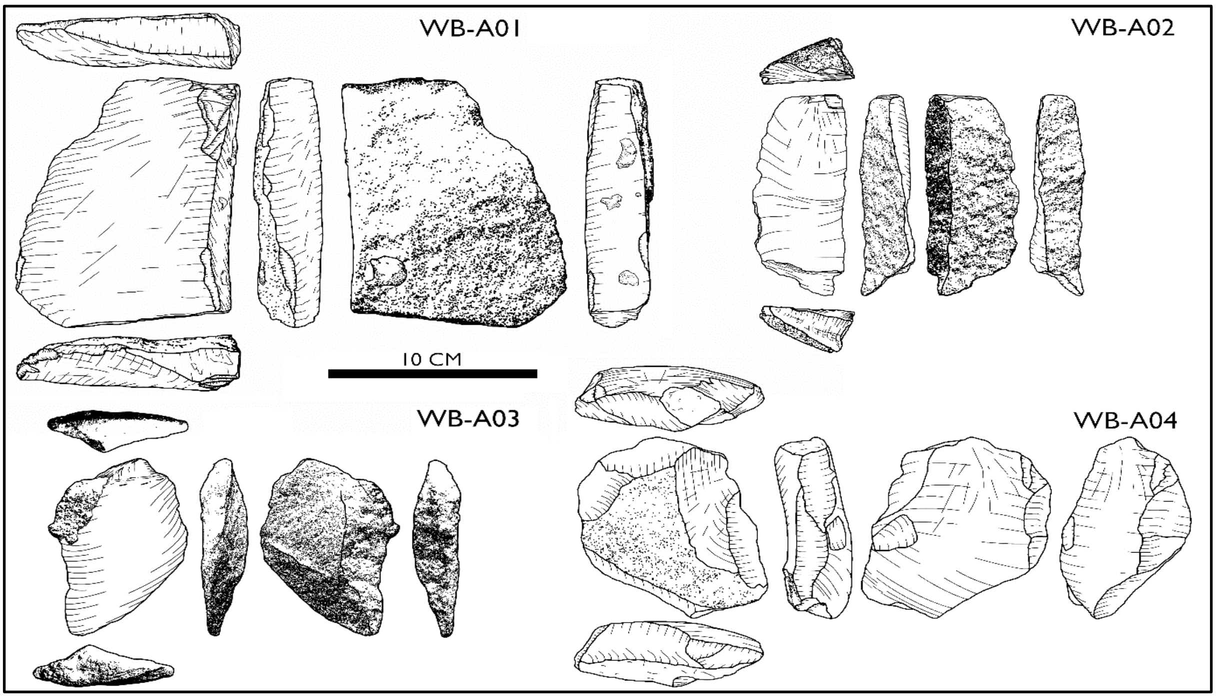

Figure 34: Lithics recovered underwater from Withnell Bay in the first formal underwater field survey in August 2023 (drawing by J. McCarthy).

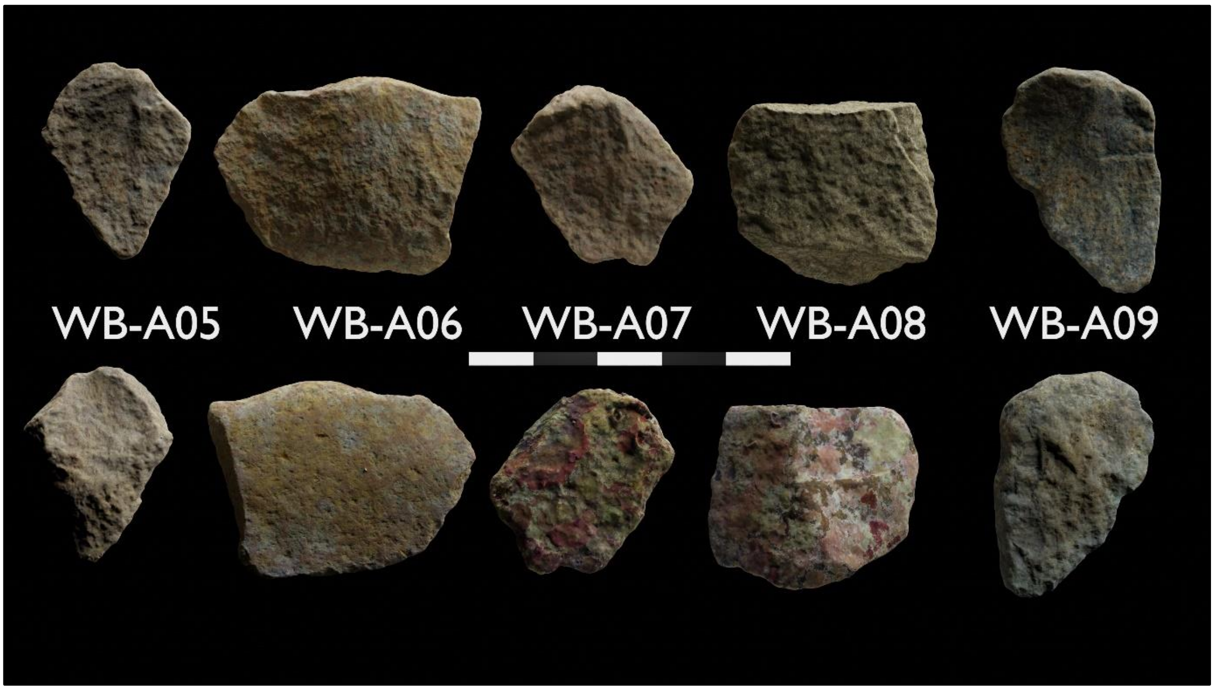

Figure 33: Ventral surfaces (top) and dorsal surfaces (bottom) of Withnell Bay lithics WB-AO5 to A09 (images by J. McCarthy). (image by J. McCarthy).

A further five lithics were identified during diving surveys conducted from the 20th until the 26th of September 2023 around the NW-H of Withnell Bay. The artefacts were analysed by lithic expert Dr Wendy Reynen (University of Western Australia) and all non-archaeological lithics were returned to the seabed. The confirmed artefacts were then drawn, and 3D scanned by Dr John McCarthy (Flinders University) and returned to MAC to be re-deposited at Withnell Bay (**Error! Reference source not found.**). The lithic assemblages that were found in September 2023 are estimated to have been within a sub-tidal context. However, further research is necessary to confirmed whether the artefacts are below the lowest astronomical intertidal zone and a tidal sensor has been deployed at Withnell Bay in February 2024, with the data retrieved and analysed later in the year.

The northern coast of Withnell Bay is significant as it represents a new location for a potential intertidal and subtidal site within Murujuga and based on confirmation of the depth which the lithics were found, could be the third submerged archaeological site found in Australia (Figure 35).

Figure removed due to copyright restriction

Figure 35: Lithic WB-A07 on the seabed, recovered at a depth of 3.4 m (photo by P. Kermeen 2023).

The environment of Withnell Bay differs from CBC and FFP as it is relatively low energy and is protected from the harsh currents experienced towards the outer islands of the Dampier Archipelago. If the site is deemed as in situ, the assemblage would be of a similar age to the CBC site (Dr John McCarthy, pers. comm. 2024).

CHAPTER 6: ARCHAEOLOGICAL INTERPRETATION OF WITHNELL BAY

In previous studies, the terrestrial landscape of the Burrup Peninsula has been systematically surveyed and Withnell Bay, Conzinc Bay, Watering Cove and Cowrie Cove areas have all been listed as ‘highly significant’ areas due to the complex assortment of archaeological sites and assemblages, which now extends underwater (Bird and Hallam 2006; Turner 1981; Veth et al. 1994; Vinnicombe 1987). The Burrup Peninsula was drowned relatively recently and archaeological deposits that date to periods of lower sea levels, similar to CBC and FFP, may be present throughout the rest of the archipelago (McDonald 2015:125; Vinnicombe 1987:53; Wiseman et al. 2020:4). At Withnell Bay the submerged lithics were recorded within rocky outcrops that extend sub-tidally along the NW-H and to the east. Similarly, artefacts located within the intertidal zone were situated near outcrops of granophyre boulders and cobbles, with artefacts located in dense patches. Towards the mangrove forest to the east, the seabed consisted of fine grained-sand and silt throughout the intertidal and sub-tidal zone made it difficult to identify lithics that may date to the Pleistocene and early-Holocene depending on the sedimentary record in this region (Figure 36). This chapter will focus on the following:

- The intertidal and subtidal sites of Withnell Bay;
- Post-glacial sea-level rise of the southern Burrup Peninsula;
- A contextual and comparative analysis of underwater and intertidal archaeology of Withnell Bay; and
- Future research which can be conducted both underwater and on-land.

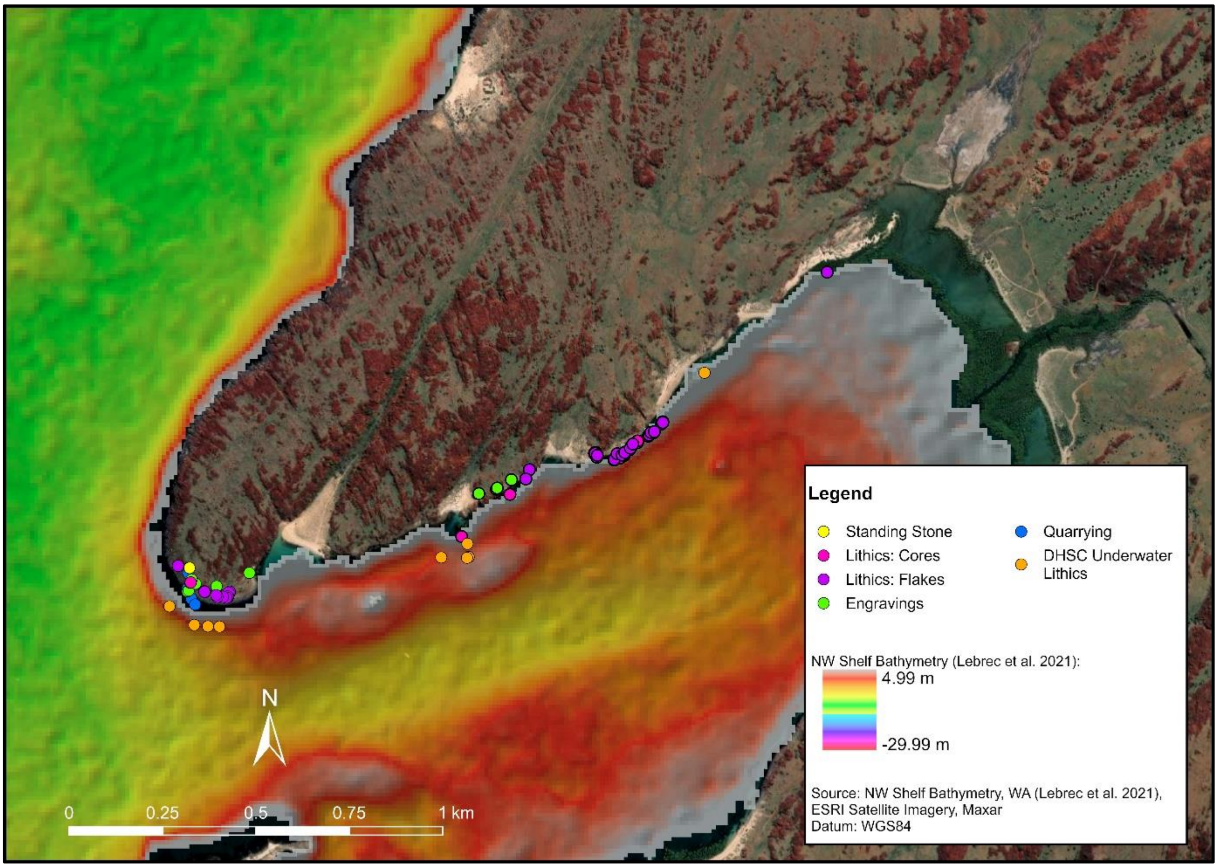

Figure 36: Intertidal and underwater archaeological sites of the north coast of Withnell Bay and NW Shelf Bathymetry (Lebrec 2021) (map by L. Brooke).

6.1 Withnell Bay as an Onshore and Offshore Site

6.1.1 The Intertidal and Sub-tidal Landscapes of Withnell Bay

The three intertidal surveys that were conducted across the northern coastline of Withnell Bay indicate a cultural landscape found across the terrestrial and underwater environment. The variety of sites represents a productive location which would have supported both terrestrial and marine subsistence activities throughout periods of sea-level rise. The geomorphology of the coastline varies from ephemeral water sources, mangrove environments with diverse biotic assemblages, rocky headlands and beaches. The sub-tidal environment varies from highly sedimented areas to the east, to a relatively sediment starved seabed to the west.

Large rocks and small cobbles to the east extended into the water but were quickly obscured due to the build-up of sand and silt. Thus, further diving surveys near the delta inlet at Withnell Bay would benefit from a detailed stratigraphic analysis of the seabed, through coring, excavation or grab-sampling which may be useful in contextualising the extent of the site (Phillipe Kermeen, pers. comm 2023). The sediment rich sea floor was noted throughout all dives that were conducted from Beach B to the Mangrove Inlet to the east. However, west of Beach B towards the NW-Headland, the seafloor was covered in thin layers of sediment and recorded as a continuous landscape similar to the intertidal and terrestrial zone.

6.1.2 Rock Art: Styles and Motifs

Petroglyphs in terrestrial environments were engraved on large boulders and rock piles, no petroglyphs were found within the intertidal zone, which is likely due to the erosion and weathering of rock surfaces. In survey one, a total of eight petroglyphs were found within a search area of 100–150 m, with some engravings found in clusters on large rocks. Survey three consisted of 12 petroglyphs found in dense clusters in an area of 100–150 m. In McDonald (2015) petroglyph assemblage sizes within 25 m are classified as small (1–5 motifs); medium (6–20 motifs); large (21–150 motifs) and complex (>1501 motifs). Survey one consists of two small assemblages, whereas survey three consists of one medium assemblage.

The techniques that were used to create the petroglyphs was not a focus of this study, however, common methods that were used to engrave the rock surface are ‘pecking’ and ‘pounding’ (Gunn and Mulvaney 2008:153). Pecking includes the pitting of the rock surface, whereas pounding bruises the shallow surface of the rock and is used to produce complex images (Bednarik 1998; Gunn and Mulvaney 2008; Maynard 1979). Alternative methods include the ‘scratching’ or ‘abrading’ of the rock surface, these techniques are recorded to a lesser extent within the Burrup Peninsula (Gunn and Mulvaney 2008).

In order to date rock art, the analysis of superimposition patterns, contrast states and the study of stylistic attributes are used to group rock art into broad temporal phases (Bednarik 2007:209). Comparatively, direct chronographic dating methods such as radiocarbon (^{14}C) and OSL are used to date mediums such as beeswax, natural coatings, rock vanishes and organic binders (Langley and Taçon 2010:70). Rock art styles in Murujuga have been split into five phases that correlate with Murujuga changing from an in-land mountain range to a modern archipelago.

Stylistic features of petroglyphs found in survey one includes both terrestrial and marine animals, geometric patterns, human figures and weathered patterns/lines. In survey one, a collection of three panels included a detailed anthropomorphic figure with enlarged feet and a ‘u-shaped’ object in each hand. To the side of the human figure, was a coastal bird with a small ‘egg’ shaped feature to the lower abdomen, along with a weathered stingray near the head of the bird. Lastly, a tail shaped image was engraved to the base of the panel, similar to a whale or dugong.

Located approximately 50–80 m east of the first panel, was two separate engravings that were found in close proximity (<10 m), the panels included a solid engraving of a turtle and another panel which had concentric bands side-by-side. The turtle panel included characteristic features of downward turned fins and an oval body, which was filled with a solid pecking pattern (Gunn and Mulvaney 2008:158). To the east, a cupule engraving was found pecked into the surface of a vertical rock.

Table 1: Petroglyph Motifs: Survey One

Motif Type	**Frequency**	**Potential Phases (McDonald 2015; Mulvaney 2011)**	**Chronological Period (McDonald 2015; Mulvaney 2011; Ward et al. 2013)**
Anthropomorphic (Human Figure)	1	Phase Five B	Late Holocene (4 ka to Present)
Whale or Dugong Tail	1	Phase Five A	Mid-late Holocene (6.5 to 4 ka)
Coastal Bird	1	Phase Four/Five	Mid Holocene to Late Holocene (8 ka to 4 ka)
Sting Ray	1	Phase Four/Five	Mid Holocene to Late Holocene (8 ka to 4 ka)
Triangle shaped ‘pecked’ design	1	Phase Four	Mid-Holocene (8 ka to 6 ka)

Concentric Bands	2	Phase Four/Five	Mid Holocene to Late Holocene (8 ka to 4 ka)
Turtle	1	Phase Four	Mid-Holocene (8 ka to 6 ka)

In survey three bird tracks were identified on smaller rocks close to the intertidal zone, a human foot was engraved alongside an outline of a fish, with another panel of vertical lines. The outline of fish species commonly occurred across survey three and was found on four panels on the NW-H, with some including linear patterns within the body.

Table 2: Petroglyph Motifs: Survey Three

Motif Type	Frequency	Potential Phases (McDonald 2015; Mulvaney 2011)	Chronological Period (McDonald 2015; Mulvaney 2011; Ward et al. 2013)
Bird Tracks	2	Phase Four	Mid-Holocene (8 ka to 6 ka)
Coastal Bird	1	Phase Four/Five	Mid Holocene to Late Holocene (8 ka to 4 ka)
Human Foot	4	Phase Four/Five	Mid Holocene to Late Holocene (8 ka to 4 ka)
Fish	1	Phase Four	Mid-Holocene (8 ka to 6 ka)
Other	4	Unknown	Unknown

As described by Mulvaney (2015) ‘the term “rock art” does not do justice to the petroglyphs, because they are a very dense and complex archive of symbolism that captures a range of social elements. The stylistic nature of engravings represents customary law and a range of social behaviours to a changing environment that was experienced by past Aboriginal populations. Petroglyphs are commonly found across steep inclines, enclosed valleys, watercourses, rockpools and along rock platforms near marine resources (McDonald and Veth 2009:56). At Withnell Bay petroglyphs were located along vertical rock surfaces near beach access points (found in survey one) and nearby quarry and knapping zones (survey three). The artistic style of the petroglyphs at Withnell Bay are speculatively identified as phases four and five that are situated around key economic zones, such as marine resources and water supplies, likely from the mid-Holocene (~8 ka) onwards (McDonald and Veth 2009:56).

6.1.3 Analysis of Intertidal and Sub-tidal Lithics

The intertidal lithic assemblages consisted of complete and broken flaked artefacts along with single and multiplatform cores. Comparatively, lithic that were found underwater by the DHSC diving and kayaking surveys consisted of flaked artefacts. Artefacts which were identified during intertidal surveys became increasingly weathered towards the waterline. The underwater artefacts showed signs of erosion and weathering, but are unlikely to have been transported long distances across the seafloor, which may indicate an in-situ site.

6.1.4 Standing Stones as Landscape Markers

A single standing stone was located at the NW-H along a ridge to the south-western side. The positioning and density of standing stones in certain areas may provide information on the cultural significance of certain landscapes. The standing stone found at the NW-H of Withnell Bay is situated in close proximity to the sea, near quarrying, reduction zones and engravings. The standing stone here may have acted as a territorial marker that could relating to a diminishing coastal plain at the end of the Pleistocene, or could act as a marker for fine-grained volcanoclastic bedrock along the ridgeline that extends throughout the NW-H (McDonald et al. 2020:9).

6.1.5 Quarrying Activities

Quarrying on moveable and immoveable stones was identified across the NW-H on granophyre boulders. This was the only location in this study where quarrying occurred throughout the three intertidal surveys. However, due to time constraints, other locations across northern Withnell Bay cannot be excluded areas which may contain fine-grained geological seams for raw materials used for lithic production (Vinnicombe 1987:67). The quarried stone occurred terrestrially and extended into the intertidal zone, which became weathered and eroded. Quarries act as a ‘fundamental starting point for reconstructing past human behavioural systems’, which assist in our understanding of human movement based on the source and discard of materials (Clarke et al. 1978; Ditchfield and Reynen 2022; Hook 2009). The artefact scatter at the NW-H was ‘variably dense’ and artefacts were identified with cobble cortex, indicating that people would have reduced the lithics on site and were in very close proximity to quarrying locations (Dr Wendy Reynen, pers. comm. 2023).

No detailed lithological study was conducted on the physical characteristics of the the quarry site within the NW-H. However, the abundance of fractures recorded across both boulders and smaller moveable rocks indicate that the geological seam was desirable, which extended underwater. This does not confirm that the quarry sites which were located to the intertidal zone represent areas that were utilised before marine transgression. As an attractive seam which is accessible from numerous locations, paired with a large tidal range, the area is frequently exposed and can used during times of sea-level stabilisation. However, the NW-H does represent a landscape which has potential to support past quarrying and reduction zones, further research is required to understand the extent of the archaeological site, both underwater and on land.

6.3 Contextual Analysis of Withnell Bay

The study of submerged cultural landscapes aids in our understanding of the first peopling of Australia, the extent of paleo-landscapes for past economies and behavioural responses to climate change post-LGM (Wiseman et al. 2021:152). As humans entered Australia between 50,000 to 65,000 years ago the continental shelf would have been a productive landscape that supported large populations (Benjamin et al. 2023:1). Murujuga has been a primary focus for the study of submerged cultural landscapes as it has dense accumulations of sites and assemblages that date to the Pleistocene (circa 50 ka) that demonstrates the shift terrestrial and marine resources as the sea transgressed across the NW of Australia (Wiseman et al. 2021:153). It is challenging to find underwater sites in situ which have survived marine inundation as environmental processes degrade drowned archaeological materials (Bailey and Flemming 2008:2159). A total of ten underwater lithics were identified across northern coast of Withnell Bay, with two concentrations of lithics to the middle and west of the bay. It is currently unknown if the artefacts are in primary or secondary contexts, and further research on tidal movement in the bay will shed light on whether the artefacts can be classified within the sub-tidal zone.

The hydrological conditions of Withnell Bay would aid in the preservation of underwater archaeological materials as the bay has a narrow entrance and is protected from harsh swells and waves (Pearce et al. 2003:24). However, a large portion of Withnell Bay is within the intertidal zone and limits areas which may contain sub-tidal sites. The underwater lithic assemblages were found 500 m apart and the morphology of the lithics identified at the spit to the east where larger when compared to the assemblage of the NW-H. The Intertidal Artefact (IA) lithics situated near the underwater assemblages of survey one included (Figure 37):

- IA113: a multidirectional core, with five negative flake scars and a step termination, this artefact was located closest to A02;
- IA114: a bi-directional core, with four negative flake scars with a step termination and plain platform, with marine concretions and shell covering a large portion of the artefact;
- IA116: a large flaked artefact with two negative flake scars; and

- IA117: a small flake, with two negative flake scars, including a feather termination.

Figure 37: Underwater lithics and intertidal lithic artefacts (map by L. Brooke).

The sample size of underwater and intertidal lithics is low and to speculate the extent and age of the sites is challenging. Three out of the four intertidal lithics were large and share some similarities to the underwater lithics in size. IA114 was found with marine concretions which might suggest that the artefact has been submerged in the intertidal zone for a while. The lithic assemblages as the intertidal surveys tracked east ranged from approximately 4–20 cm. The NW-H lithic assemblage was variably dense and artefacts ranged from approximately 2–12 cm. The NW-H artefacts in comparison to the east of the bay have cobble cortex and were likely to have been reduced from locally available materials. A high density of lithic artefacts was recorded on the flat plateau which overlooked Withnell Bay and as lithic artefacts were located closer to the waterline the edges became more weathered (Figure 38).

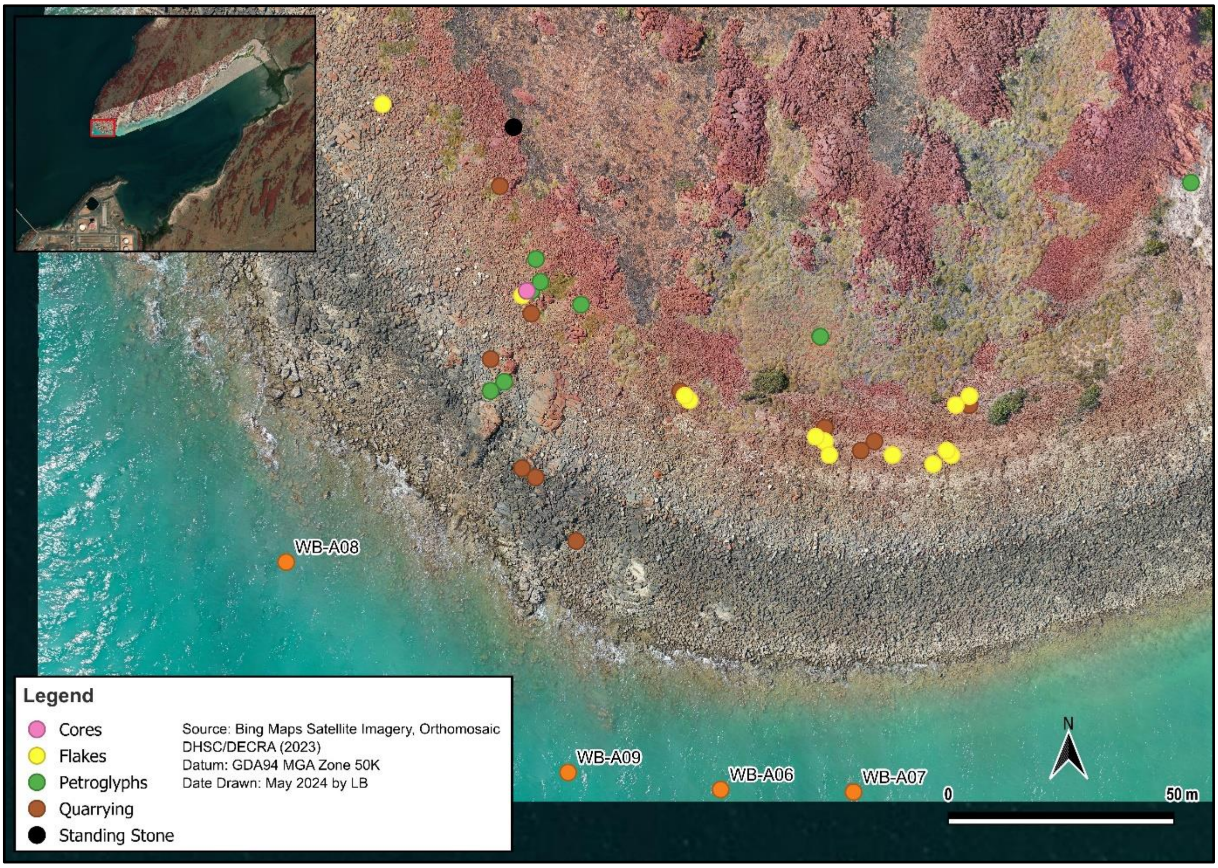

Figure 38: Underwater and intertidal assemblages of the NW-H (map by L. Brooke).

The underwater lithics WBA05–09 were small, locally sourced and reduced at the NW-H and represents a site that extends across the intertidal and sub-tidal zones. The underwater lithic assemblages at the NW-H either represents a site that can be dated to a period before marine transgression, or, a continuation of the terrestrial site during sea-level stabilisation. The size and morphology of the eastern spit assemblage is larger and likely represents artefacts which are of a different age in comparison to the west, with similar characteristics of lithics recorded across the nearshore environment in survey one and two. However, the assemblages would benefit from further research on artefacts characteristics such as retouch and comparison to sites such as of Dolphin Island, the Gidley Islands, CBC platform and channel (Benjamin et al. 2020:25; Dortch et al. 2018:516; Hiscock and Attenbrow 2003:240; Leach et al. 2021:257). The minimum ages reported for the CBC site was 7000 cal BP, whereas the FFP site is older and dated to a minimum age of 8000 cal BP. Withnell Bay is situated further south and the underwater assemblage if deemed in situ, would have a minimum age of at least 6,000 years old. The shallow nature of the bay, paired with Dampier Island being one of the last areas to become separated the mainland of Australia post-LGM, the embayment would have only been submerged during the mid-Holocene (McDonald 2015:126).

6.4 Future Research Prospective at Withnell Bay

Future underwater research conducted at Withnell Bay may benefit from concentrated diving surveys around areas where bedrock noticeably extends into the waterline, particularly following the NW-H towards Conzinc Bay to the north (Figure 39). As the east of Withnell Bay has thick layers of sediment that is deposited on the sea floor, potential coring surveys may aid in understanding the matrix of the tidal flat. A minimally invasive technique of diver assisted percussion coring devices for micro-sampling to the east and provide a contextual analysis of sediment build up and how this may affect the visibility of sites in Australia (Horlings 2012:191). Coring methods including water jet coring and micro-geoarchaeological techniques have been used on submerged prehistoric sites such as Atlit-Yam and Neve Yam in Israel and have been proposed as a time and cost-effective solution to exploring sub-tidal sites across shallow continental shelves globally (Ramirez 2021:105480).

A detailed terrestrial and intertidal analysis of the NW-H, focusing on diagnostic features of lithic artefacts, the distribution of quarrying activities and stylistic features of engravings will provide a more wholistic overview of the area. This compliments ongoing underwater research as land-based research will aid in contextualising the portion of the bay which is prospective to preserving underwater archaeology. The west of Withnell Bay is a priority for ongoing underwater diving led research, which extends around the headland, due to access to raw materials, paired with the dense accumulation of artefacts which is contiguous along the coast. The ‘Australia Model’ adapted by the DHSC for the detection of submerged cultural landscapes will continued to be improved as more sites are identified in the intertidal and sub-tidal zones (Wiseman et al. 2021:169). Withnell Bay is similar to the CBC assemblage and surrounding Gidley Islands, which consists of a culturally modified landscape that extends both onshore and offshore.

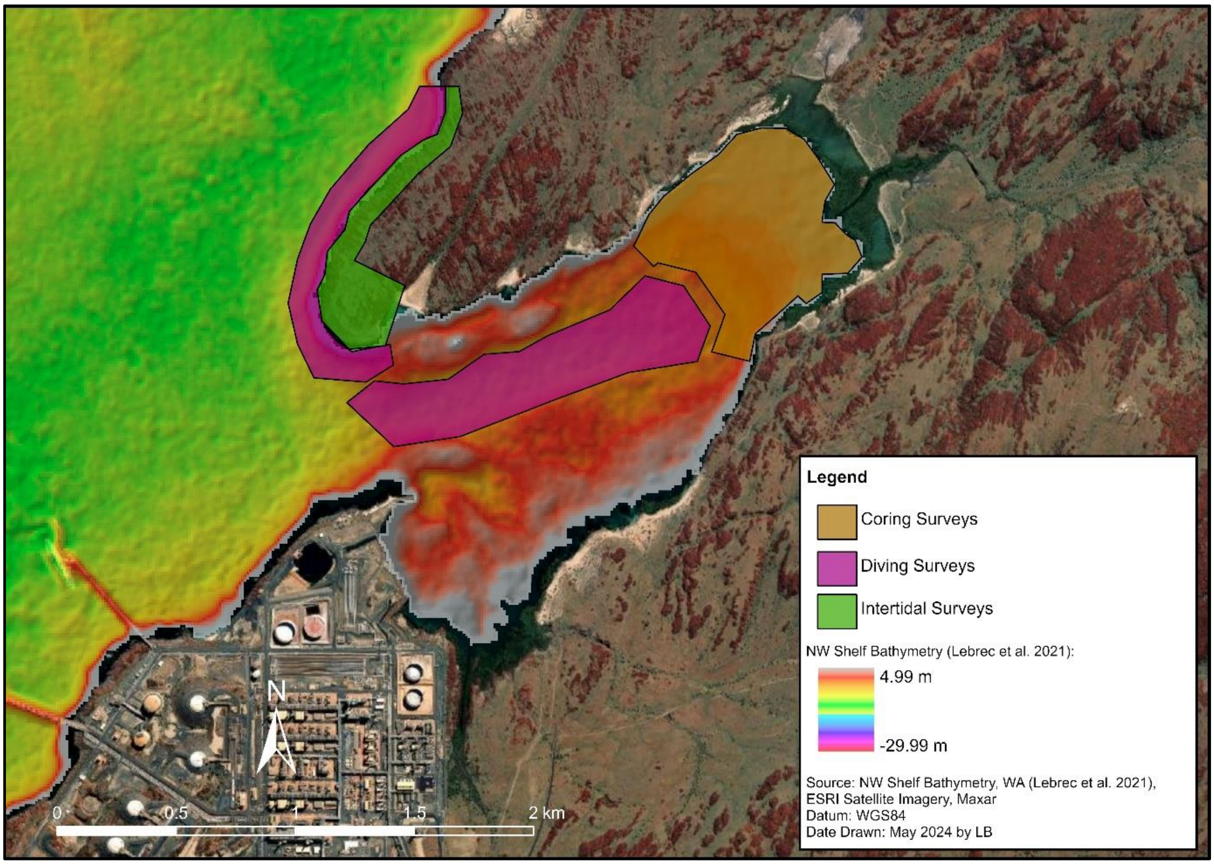

Figure 39: Future underwater research that can be conducted at Withnell Bay, based on observations from 2023 fieldwork (map by L. Brooke).

CHAPTER 7: CONCLUSION

The research aims and objectives of this thesis was to use a desk-based approach and intertidal archaeological survey as a way of contextualising underwater sites within the broader cultural landscape. The study of northern-Withnell Bay as a site which extends both on land and underwater, demonstrated that it is possible to conduct near-shore research adjacent to diving surveys which is critical in determining how sites connect and interact with the surrounding landscape. The ongoing identification of submerged archaeological sites demonstrates that cultural landscapes (Sea Country) range from the shallow intertidal to the deepest parts of the continental shelf and research must be done in conjunction with Elders and Traditional Knowledge (Benjamin et al. 2020:12; Yunupingu and Muller 2012:158). In particular, the nearshore and underwater environments must be viewed as a cultural continuum as Dreaming stories are intertwined with the entire regions across Australia, it is redundant to view submerged sites as an isolated phenomenon (Flatman 2007:90; Fowler 2019:169).

Submerged landscape archaeology in Australia is still in its early stages and the ongoing identification of sites will result in the refinement of methodology (Wiseman et al. 2021:168). Time and resources devoted to intertidal survey and broad-landscape contextualisation, when applicable, is useful in conjunction with underwater research. The petroglyphs panels located above the intertidal zone represent a maritime landscape from the transition period between the Pleistocene to Holocene from approximately 8 ka onwards (McDonald 2016; McDonald and Veth 2015; Mulvaney 2011). The speculative dates of the petroglyphs provide a broad range for the intertidal landscape of northern Withnell Bay which may correlate with the surrounding lithic assemblages and sites. Quarry sites and knapping zones were located along a granophyre outcrop which extended sub-tidally, with a single standing stone found in this area which may have represented a landscape marker for access to raw materials. Future diving investigations of the NW-H along areas of outcropping granophyre are imperative to continue documenting the submerged landscape of Withnell Bay.

The intertidal lithic assemblages to the NW-H represent a continuous site which extends terrestrially and underwater with similarities in size and morphology. The lithics towards the eastern section of Withnell Bay are larger and seemingly extend underwater and through the intertidal zone, this area would benefit from further research which examines the stratigraphy of this area in relation to buried artefacts. When comparing Withnell Bay to sites such as CBC and FFP towards the outer islands of the Dampier Archipelago, modifications may be necessary to accommodate for changing the geomorphology between the sediment starved channels and sediment rich embayments.

The methods used in this study demonstrate that a cultural landscape extends throughout Withnell Bay both above and below the waterline. Signifying that submerged archaeological studies in Australia benefit from contextualisation of broad environments to provide comparable archaeological and geomorphological context, rather than assessing underwater sites in isolation. As the study of submerged landscapes evolves it is important to include Aboriginal community engagement, cross-disciplinary methodology and to compare underwater sites against the broader terrestrial environment. This ensures that offshore sites are understood as part of a cultural continuum which extends both on-land and underwater.

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APPENDICES

Appendix A:

Table 3: Fischer (1995) suggested that this model could be applied in similar submerged settings across Europe (and globally) that are sheltered from extreme wave action and argues that artefactual remains can endure inundated environments despite erosion and sedimentation processes (Fischer 1995:57). Thus, described survey investigations in a three-step system (Fischer 1993)

Phase	Description
I	Map plotting
II	Localisation and delimitation for site by echosounder
III	Marking of theoretical site and diving survey

Table 4: Benjamin (2010) reviewed the 'Danish Model' for submerged site prospection, suggesting that methods used in the Baltic Sea may not be applicable for other, high-energy environments. Thus, a more robust, six-step system was created and used in Australia (Benjamin 2010:258)

Phase	Description
I	Regional Familiarisation
II	Ethnography and History
III	Map, Chart, Aerial Analysis and Location Plotting
IV	Observation of Potential Survey Locations, Physically and with Sonar
V	Marking of Theoretical Site with GPS and Diving to Investigate
VI	Post-Fieldwork Analysis, Interpretation and Dissemination

Appendix B:

Table 5: Common Aboriginal stone structures and features in Murujuga (Beckett 2021:49).

Number	**Description**
1	Standing stones
2	Placed stones
3	Cairns
4	Circular structures
5	House Structures
6	Cockpits
7	Linear Structures
8	Stone walls
9	Stone Terraces
10	Fish traps
11	Hunting hides
12	Stone pits
13	Complex arrangements

Appendix C:

Table 6: Survey one lithic artefact locations (GDA94 MGA Zone 50K)

Number	GPS Order	Description	Type	Eastings	Northings
1	113	Multi-Platform Core	Granophyre	477603	7724734
2	114	Single Platform Core	Granophyre	477724	7724839
3	116	Flaked Artefact	Granophyre	477764	7724878
4	117	Flaked Artefact	Granophyre	477773	7724901

Appendix D:

Table 7: Survey two lithic artefact locations (GDA94 MGA Zone 50K)

Number	GPS Order	Description	Type	Eastings	Northings
1	123	Multi-Platform Core	Granophyre	478107	7725021
2	124	Single Platform Core	Granophyre	478107	7725019
3	125	Flaked Artefact	Granophyre	478086	7724996
4	126	Flaked Artefact	Granophyre	478077	7724994
5	127	Flaked Artefact	Granophyre	478073	7724988
6	129	Flaked Artefact	Granophyre	478032	7724965
7	130	Flaked Artefact	Granophyre	478026	7724955
8	131	Flaked Artefact	Granophyre	478012	7724944
9	132	Flaked Artefact	Granophyre	478013	7724945
10	133	Flaked Artefact	Granophyre	478005	7724938
11	134	Flaked Artefact	Granophyre	477993	7724941
12	135	Flaked Artefact	Granophyre	477986	7724927
13	136	Flaked Artefact	Granophyre	477943	7724937
14	137	Flaked Artefact	Granophyre	477938	7724942
15	138	Flaked Artefact	Granophyre	477938	7724944
16	139	Flaked Artefact	Granophyre	477939	7724944
17	140	Flaked Artefact	Granophyre	477936	7724942
18	128	Multi-Platform Core	Granophyre	478044	7724973
19	135	Multi-Platform Core	Granophyre	477986	7724927

Appendix E:

Table 8: Survey three lithic artefact locations (GDA94 MGA Zone 50K)

Number	GPS Order	Description	Type	Eastings	Northings
1	NA	Multi-Platform Core	Granophyre	476924	7724619
2	NA	Flaked Artefact	Granophyre	477022	7724596
3	NA	Flaked Artefact	Granophyre	477019	7724594
4	NA	Flaked Artefact	Granophyre	477018	7724583
5	NA	Flaked Artefact	Granophyre	477017	7724584
6	NA	Flaked Artefact	Granophyre	477014	7724581
7	NA	Flaked Artefact	Granophyre	477005	7724583
8	NA	Flaked Artefact	Granophyre	476990	7724586
9	NA	Flaked Artefact	Granophyre	476990	7724586
10	NA	Flaked Artefact	Granophyre	476991	7724583
11	NA	Flaked Artefact	Granophyre	476988	7724587
12	NA	Flaked Artefact	Granophyre	476960	7724595
13	NA	Flaked Artefact	Granophyre	476959	7724596
14	NA	Flaked Artefact	Granophyre	476923	7724618
15	NA	Flaked Artefact	Granophyre	476892	7724660