Routledge
Taylor & Francis Group

Australian Archaeology

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/raaa20

# Late Pleistocene scaphopod beads from Boodie Cave and deep time traditions of personal ornamentation in northwest Australia

Fiona Hook, Michelle C. Langley, Sean Ulm, Jo McDonald & Peter Veth

**To cite this article:** Fiona Hook, Michelle C. Langley, Sean Ulm, Jo McDonald & Peter Veth (13 Nov 2024): Late Pleistocene scaphopod beads from Boodie Cave and deep time traditions of personal ornamentation in northwest Australia, Australian Archaeology, DOI: 10.1080/03122417.2024.2416278

**To link to this article:** https://doi.org/10.1080/03122417.2024.2416278



Published online: 13 Nov 2024.

AUSTRALIAN ARCHAEOLOGY
https://doi.org/10.1080/03122417.2024.2416278

Routledge
Taylor & Francis Group

ARTICLE

OPEN ACCESS Check for updates

# Late Pleistocene scaphopod beads from Boodie Cave and deep time traditions of personal ornamentation in northwest Australia

Fiona Hook[a], Michelle C. Langley[b,c], Sean Ulm[d], Jo McDonald[a,e,f] and Peter Veth[a,e,f]

[a]Archaeology Discipline, Social Sciences, School of Social Sciences, The University of Western Australia, Perth, Australia; [b]Archaeology, School of Environment and Science, Griffith University, Brisbane, Australia; [c]Australian Research Centre for Human Evolution, Griffith University, Brisbane, Australia; [d]ARC Centre of Excellence for Indigenous and Environmental Histories and Futures, James Cook University, Cairns, Australia; [e]Centre for Rock Art Research + Management, School of Social Sciences, The University of Western Australia, Perth, Australia; [f]ARC Centre of Excellence for Indigenous and Environmental Histories and Futures, School of Social Sciences, The University of Western Australia, Perth, Australia

**ABSTRACT**

Tubular segments of Scaphopoda (tusk shell) were traditionally used by Aboriginal peoples in the manufacture of ornate bead necklaces across northwest Australia. Twenty-seven scaphopod shell beads were recovered from Boodie Cave on Barrow Island dating to between 13,500 and 10,600 cal BP. We compare the Boodie Cave bead assemblage to historical necklace collections as well as experimental studies on scaphopod blanks to characterise bead manufacture, breakage, use-wear, and placement patterns. Results demonstrate that the Boodie Cave beads are larger than other northwest Australian collections; have been manufactured by an anvil-rested percussion technique; have signs of use-wear in the form of polish and rounding but are less curated than specimens from the inland Kimberley. The use-wear study identified that the Boodie Cave beads were strung in a series in a pattern not observed in historical scaphopod necklaces from northern Australia. This patterning may represent a regional variation in display and technological organisation and was likely part of wider ornamental practices documented in historical sources. In all, the Boodie Cave beads provide early and additional evidence for the trade, wearing, and loss of scaphopod beads by mobile hunter-gathers on a dynamic coastline.

**ARTICLE HISTORY**
Received 21 April 2024
Accepted 10 October 2024

**KEYWORDS**
Aboriginal Australia; adornment; bead manufacture; bead morphology; cultural traditions; experimental archaeology; organic technology; shell beads; use-wear; tusk shell; trade

## Introduction

Excavations in Boodie Cave on Barrow Island off northwest Western Australia in Thalanyji Country (Figure 1) recovered 27 scaphopod segments in deposits dating between 13,500 and 10,600 cal BP (Veth et al. 2017), making these artefacts the earliest shell beads identified in quantity near the coast in a Late Pleistocene context (cf. Balme and O'Connor 2017). Previously, scaphopod beads have been reported in rockshelter deposits spanning the Late Pleistocene to Late Holocene in Cape Range (Morse 1988, 1993a, 1993b) and the Kimberley (Balme and O'Connor 2017; Balme et al. 2018; Maloney et al. 2018), and in Late Holocene open sites on Murujuga (McDonald et al. 2023a). The new Boodie Cave finds provide an opportunity to explore a wider and older northwest Australian distribution of scaphopod bead ornaments.

Beads have long been used by archaeologists as markers for tracking complex social behaviours (Balme and Morse 2006; Balme et al. 2009; d'Errico et al. 2005; Langley et al. 2019; Mellars 2005; Stiner 2014) as they are inherently symbolic, conveying meanings within and between groups. Beads were prized and traded across large distances in Australia, with men, women, and children using them in both secular and ceremonial contexts (Balme and O'Connor 2019; McAdam 2008). They are, however, rare in Australian archaeological sites. Thus, the recovery of a sizeable assemblage of scaphopod beads dating to the Late Pleistocene/Early Holocene transition warrants their comparison to other shell bead assemblages from the northwest, historical collections and from understandings provided by experimental archaeology.

Our study set out to first determine whether the 27 scaphopod artefacts from Boodie Cave are, in fact, beads and to investigate how these items were made and strung – were the beads from Boodie Cave strung in series (in nested fashion) like those in historical collections? Or were they strung tapered end-to-end? This study also compares the Boodie Cave beads with

CONTACT Fiona Hook fiona.hook@research.uwa.edu.au Archaeology Discipline, Social Sciences, School of Social Sciences, The University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia.

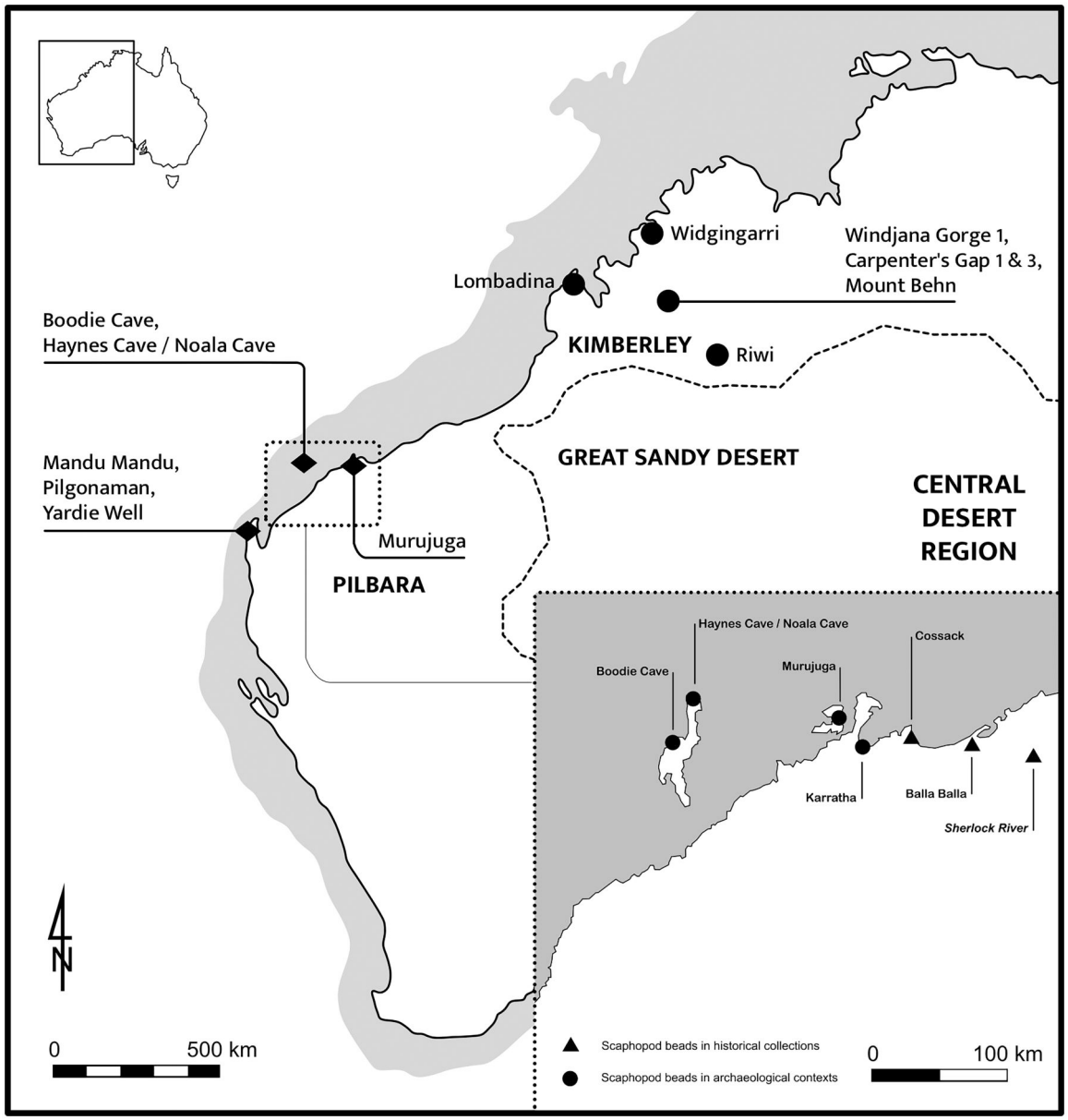


**Figure 1.** Australian places mentioned in the text (illustration by Adam Black).

known examples from southern Kimberley archaeological sites, including Carpenters Gap 3, Mt Behn, and Riwi, with 10 specimens recovered from each of these sites (Balme and O'Connor 2017; Balme et al. 2018). The scaphopod beads from the Kimberley sites are described by Balme and O'Connor (2017:11–12) as small and displaying varying degrees of use-wear including 'notching, micro-chipping, and rounding'. They conclude that this noticeable level of polish and rounding is a result of the long distances they have been exchanged from the coast (≥c.500 km) and high levels of reuse and curation (Balme and O'Connor 2017:16; Balme et al. 2018:270; Maloney et al. 2018). A key aim of our study was to determine the wear patterns on the Boodie Cave scaphopod beads. The novel experimental use-wear analysis detailed in this paper provides a framework for more accurately comparing scaphopod bead use-wear from archaeological sites and historical collections and this is the first experimental use-wear analysis of scaphopod beads undertaken in Australia.

## Boodie Cave: the archaeological context

Archaeological deposits from Boodie Cave on Barrow Island, have provided evidence for the earliest use of marine resources in Australia (Veth et al. 2017), with c.20 $m^3$ of cultural deposits excavated between 2013 and 2015 (Figure 2). Thalanyji people who are based in Onslow have a cultural connection with Barrow Island and are an integral part of the research project.

An intensive dating program revealed first occupation occurred at Boodie Cave between 51.1 and 46.2 ka, overlapping with some of the earliest uncontested dates for the occupation of Australia.

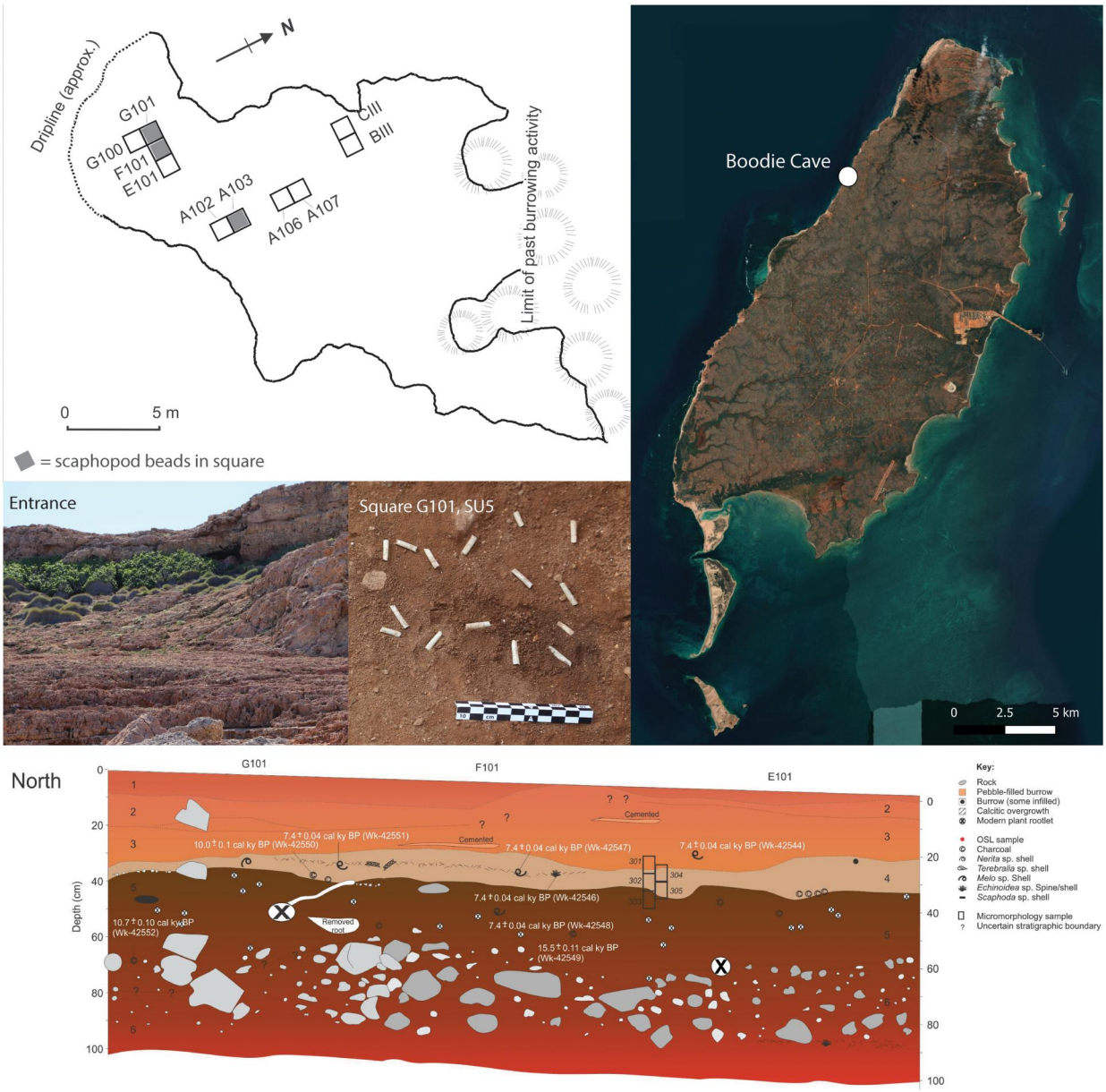


**Figure 2.** Plan of excavated squares, photographs of Barrow Island, Boodie Cave rockshelter, the in situ beads, and cross-section of deposit (image by Barrow Island Archaeology Project).

Marine resources were a part of the dietary assemblages from earliest occupation and continued to be transported to the cave in varying quantities through time, despite fluctuating sea levels and extensions of the coastal plain. The changing quantities of marine fauna through time are seen to reflect the varying distance of the cave from the contemporaneous shoreline (Veth et al. 2017). The dietary breadth of both arid zone terrestrial fauna and marine species increased after the Last Glacial Maximum and significantly so by the Early Holocene (Veth et al. 2017). The cave was abandoned by 6.8 ka when the island was located some c.50 km distant from the mainland.

A total of 27 scaphopod artefacts were recovered from three squares (A103, F101, and G101) with all but one recovered from Stratigraphic Unit 5 (Figure 2). Nineteen were found in one excavation unit (Square G101, SU5) with one specimen directly dated to 11,025–10,710 cal BP (Wk-13339b). Fifteen were oriented horizontally in fine-grained sediments within c.50 cm of each other. Stratigraphic Unit 5 in G101 is dated to between 13.5 ka (L008/15-8) and 10.6 ka cal BP (Wk-42588) neatly bracketing the direct-dated scaphopod artefact. One scaphopod artefact was found just below the densest midden layer (SU2) which terminates at 6.8 ka cal BP (Veth et al. 2017:24). The beads are associated with a rich cultural layer that includes the remains of over 40 different species of marine invertebrates, *Melo* shell knives with associated shell manufacturing debris, turtle bones, cooking hearths stones, diverse macropod remains, and a dense assemblage of lithics (Veth et al. 2017).

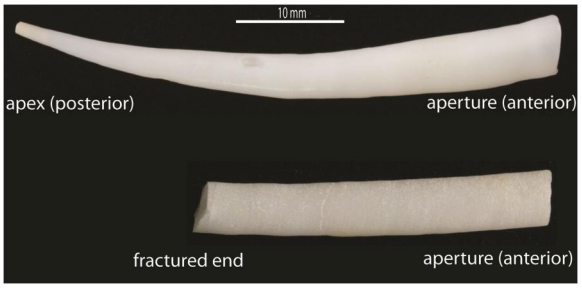


**Figure 3.** Whole *Laevidentalium lubricatum* (above) and scaphopod bead (below) including terms used in text (image by Fiona Hook).

## Scaphopod beads in Australian archaeology, material culture and historical observations

### Distribution of taxa in northwest Australia

Scaphopod shell beads are often classified in the archaeological literature under the genus *Dentalium* or the common name 'tusk shell' (e.g. Morse 1988); however, there are eight scaphopod families and 108 species reported in Australian waters (Lamprell and Healy 1998). Of the 108 species, 42 occur off the northwest Australian coast, with 17 of these species in the genus *Dentalium*. Scaphopod general habitat is sandy substrate both close to shore and in deeper water. They are often washed up on beaches, where the shells can be collected and made into beads by breaking the shell, creating a hollow cylindrical bugle bead that can be easily threaded (Balme and O'Connor 2017:15). The beads do not retain the posterior portion of the shellfish, which makes it impossible to identify them to species level using morphological attributes (Figure 3). Therefore, we adopt the lowest taxonomic rank identifiable – the Class Scaphopoda.

### Scaphopoda macro- and microstructure

The macrostructure of Scaphopoda presents as curved and tubular, forming a spiral of increasing width from the apex (posterior) to the aperture (anterior) (Figure 3). A simple shellfish, their spiral is symmetrical with a planar orbit (Vermeij 1995:15–18). Some species in the family Gadilinidae have a central bulge rather than a curved taper. Surfaces vary from glossy smooth to transverse growth lines, with some species exhibiting transverse or longitudinal striae. Scaphopods are entirely composed of aragonite with two thin homogeneous surface layers located either side of a thicker, crossed-lamellar middle ultrastructure (Smith and Spencer 2016). This construction makes them extremely brittle, especially when pressure is applied; however, it does produce a generally clean and even break with consistent force.

Whole scaphopod shells provide a substantial blank from which individual beads can be manufactured to the required length; however, the whole shell is not suitable for use as an ornament as the apical (posterior) end is too narrow to thread (Figure 3). To function as ornaments, they must be broken into segments with the narrow, posterior portion discarded. The beads can be manufactured into a finished state in a relatively short period of time and can be made of varying lengths depending on the technique used to break the shell. Therefore, once blanks are collected and cached their utility in producing many bead segments is high and energy efficient.

### Archaeological examples

Ten specimens from the site of Riwi in the southern Kimberley are the oldest scaphopod beads from Australia, dating to 34,000 cal BP. An anomalous direct date of 7,644–7,459 cal BP on one of the beads is attributed to remineralisation of the dated bead (Balme and O'Connor 2017:9–10). Scaphopod shell fragments, which are not yet identified as beads in the literature, occur in units dated to between 26,000 and 22,000 cal BP, and in Late Holocene units from Mandu Mandu Creek Rockshelter at Cape Range (Morse 1988, 1993b). Most of the beads from the southern Kimberley sites date to the Late Holocene (Balme and O'Connor 2017; Balme et al. 2018; Maloney et al. 2018). A scaphopod posterior fragment from Haynes Cave on the Montebello Islands is dated from contexts between 9,251–8,642 cal BP (Wk-2914) (Veth et al. 2007:10, 31), while a scaphopod bead was also identified by Fiona Hook in a recent reanalysis of Noala Cave, also in the Montebello Islands, in an excavation unit dated to 11,303–10,206 cal BP. Four scaphopod segments were recovered from units dating between 495 and 270 cal BP in Eastern Beach Red Dune Midden 1 near Lombadina on the Dampier Peninsula (Litster et al. 2020).

Research on Enderby Island (Murujuga – Dampier Archipelago) provides evidence for the manufacture of scaphopod beads between 1,200 and 1,600 years ago (Goldwyer 2018; McDonald et al. 2023a). Here, bead manufacturing debris was found amongst an extensive rock art and midden complex, located several kilometres from the current coastline, representing the first reported archaeological evidence of a scaphopod bead production site in Australia. Two contiguous 0.5 m × 0.5 m excavation squares contained 961 scaphopod specimens, of which 575 are posterior portions, two are whole shells, six are anterior portions, 364 are medial portions and 14 are labelled as 'NA' (Goldwyer 2018; McDonald et al. 2023a:198). The results clearly show that a focused activity at this site was bead manufacturing with 575 posterior fragments present in the

assemblage. Posterior fragments are not used as beads as their apertures are too small for threading. The experimental work shows that percussion manufacture results in a mean debris fragment (medial and posterior) number of 1.5, the historical necklace analysis shows a dominance of anterior beads which is also replicated in the archaeological collection. Therefore it is concluded that all non anterior fragments from the Enderby Island site are manufacture debris, with only six beads (anterior fragments) present in the assemblage, with 596 anterior portions missing, presumably used to make necklace(s).

Scaphopod beads have been recovered from three other Murujuga sites (Goldwyer 2018). From the Burrup site Old Geos 17, beads were recovered from within a stone structure, while another three scaphopod specimens found in the open excavation here were interpreted as broken fragments of the same shell. The beads were probably lost from a necklace by someone using the stone structure between 1,100–760 cal BP (McDonald et al. 2023b). Two sites on Rosemary Island also provided evidence for bead wearing in the Mid-to-Late Holocene (McDonald et al. 2023c). At Chookie Bay, to the north of the island, 11 scaphopod beads were found, with use-wear and weathering from this dated sequence indicating that the beads were lost by their wearers between 4,000 and 3,000 years ago – and again in the last millennium (McDonald et al. 2023c). At Wadjuru Pool, to the south of Rosemary Island (Berry 2018; McDonald et al. 2023c), two scaphopod beads were found in Late Holocene deposits. The uppermost bead was found to have polished edge-wear on its outer rim and the remains of grass fibre string within its interior (McDonald et al. 2023c; see also Stephenson 2016) and is interpreted to have been lost by its wearer between 1,500–500 cal BP (McDonald et al. 2023c).

## Material culture collections and historical observations

In Australia, necklaces strung with scaphopod beads were historically worn as headbands, chokers, necklaces, across the chest and under the arms by men, women, and children (Peggs 1903; Roth 1910; Thomson 1934). They were used by Aboriginal people for a range of functions. Women in Arnhem Land used them as ceremonial dress and in mourning. In Broome, women wore scaphopod bead necklaces during courting and once married the necklaces were put aside for special occasions (Peggs 1903). In the Gulf of Carpentaria scaphopod necklaces were used in burials (Schall 1985). In the Kimberley, scaphopod bead necklaces were also worn for secular purposes by men, women, and children. Today in the coastal Kimberley, scaphopod necklaces are made by women for their sons to wear during initiation ceremonies. Kim Akerman observed women at Mowanjum and One Arm Point making scaphopod shell bead necklaces during the 1970s (Kim Akerman, pers. comm. 2017). He reported that women placed shells on a stone anvil and applied a short sharp blow, causing the shell to break in half (percussion technique). This sharp impact produced one whole bead, from the anterior portion, ready for stringing into long loops (Figure 4). Moya Smith at the same time observed women at Lombadina making scaphopod beads where they applied direct pressure from the sharpened edge of a metal knife snapping the shell in half while it rested on the anvil (saw and snap technique) (Balme et al. 2018:268). This technique produced a fractured end with 'perpendicular straight edges, oblique straight edges, and edges with small chips presumably from the pressure of the knife' (Balme et al. 2018:268).

In reviewing bead distribution and use in Aboriginal Australia, McAdam (2008) viewed 81

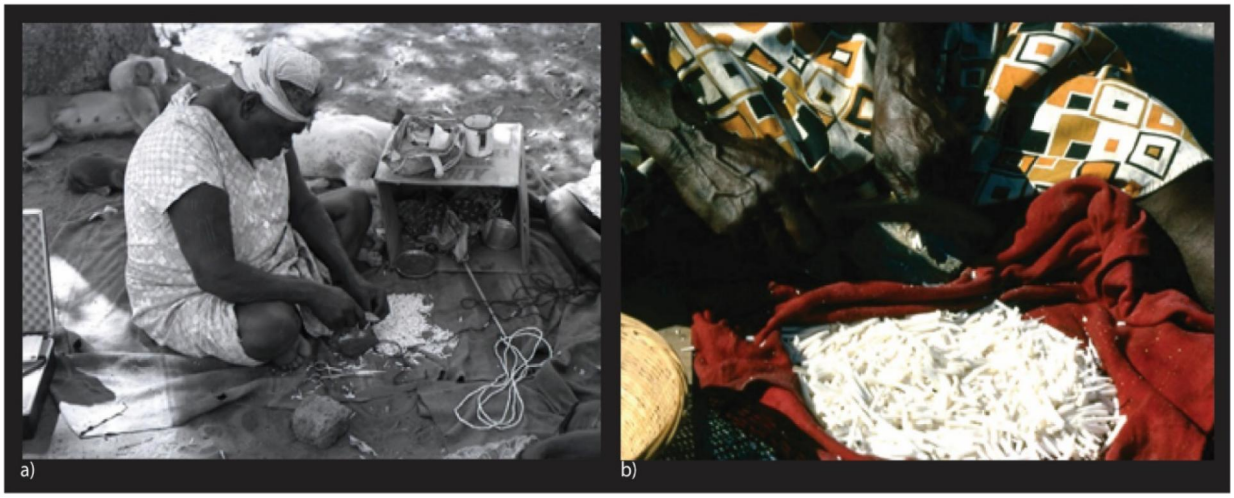


**Figure 4.** (a) Sarah Ah Choo cracking scaphopod shells against an anvil with the back of a knife, One Arm Point 1974; (b) May Langi breaking scaphopod shells to thread on hair string as ornaments, Mowanjum, August 1974 (image by Kim Akerman).

scaphopod historical objects held in nine museums in Australia. Her analysis determined that all scaphopod beads were strung as necklaces, not as pendants, and that tusk shell beads were the second most common bead type after those made on pearl shell. The scaphopod necklaces were collected from northern Australia (West Cape York to Roebourne) and all from locations close to the sea (McAdam 2008:235, 237, 243). Scaphopod beads were identified by McAdam as the dominant shell bead in the Timor Sea region, primarily found in the Kimberley ($n = 64$), with nine ornaments in Arnhem Land and just four in Cape York. McAdam did not investigate specific stringing styles of scaphopod beads but focussed on broader classification of the different forms of necklace structures. For example, 'whole shells or shell segments attached to a single continuous fibre by threading the fibre through an aperture that may be natural' (McAdam 2008:244) which were classified as SH01 and 'shell sections have been cut or broken to form rectangular or square shaped segments; segment edges may be sanded or polished to smooth' (McAdam 2008:253) classified as SH02. From the three images of scaphopod necklaces collected from the Kimberley ($n = 2$) and Gulf of Carpentaria ($n = 1$) all are strung in a nested fashion (McAdam 2008:244–246).

Collections of necklaces made by the nineteenth century antiquities collector Eugene Clement are particularly significant. While travelling throughout the northwest between 1896 and 1899, Clement collected at least 19 necklaces (known as *djuba*) from the Pilbara (Clement and Schmeltz 1903), with one being a scaphopod shell necklace collected from Balla Balla on the boundary of Ngarluma/Karierra Country (National Museum of Scotland A.1898.372.55) (Figure 5). *Djuba* are described as 'hair necklaces' referring to the raw material onto which beads were strung (Clement and Schmeltz 1903:19). The *Collecting the West* database (Alistair Paterson, pers. comm. 2023) has identified nine scaphopod bead necklaces collected from the Pilbara, some of which were collected by Clement, including the one curated in the Western Australian Museum and the other eight located in United Kingdom museums.

## Methods

### Experimental program

Experimental archaeology has previously been carried out on scaphopod shells to compare them with beads from archaeological contexts in Europe (Vanhaeren and d'Errico 2001) and the Middle East (Campbell 2017; Larson 1978). Experimental studies identified several techniques that could be used to make scaphopod beads including percussion, snapping, pressure, and inscribing. These studies utilised a variety of scaphopod species, many smaller than the species found in Australian waters, consequently often resulting in the manufacture of smaller beads than those found in Australian archaeological sites. When using smaller species, the production of even and replicable beads is a labour-intensive process. These three international studies (Campbell 2017; Larson 1978; Vanhaeren and d'Errico 2001) did not use the manufacturing techniques used by Kimberley Aboriginal people in Australia (Balme et al. 2018; Kim Akerman, pers comm. 2017). As such, an experimental study using the bead manufacture techniques in the Kimberley was conducted by the authors FH, MCL, and SU in 2017.

The aims of the experimental study were to: (1) determine if different manufacturing techniques resulted in identifiable characteristics; (2) identify the different ways the beads were strung together and what use-wear resulted; and, (3) provide a baseline for the number of hours a bead needs to be worn before use-wear will result. Our study involved

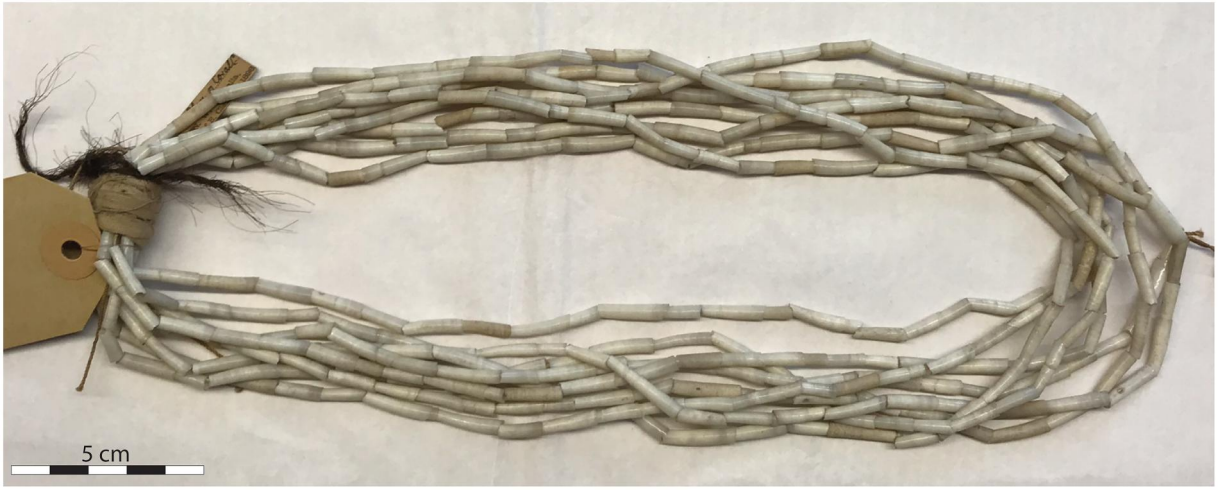


**Figure 5.** Museum held necklace with label stating: "Necklace or djuba of dentalium entale? strung on thread" collected by Clement in 1898 from Balla Balla, Pilbara (National Museum of Scotland, Edinburgh A.1898.372.55) (image by Fiona Hook).

the replicative manufacture of 30 beads from complete *Laevidentalium lubricatum* shells and observations of manual use-wear patterns from two strung sets (each) of 10 shell beads.

The scaphopod bead manufacturing experiments were carried out in the University of Western Australia Archaeology Laboratory. The 30 beads were made from *Laevidentalium lubricatum* shells collected in Port Hedland by shell collector Merv Cooper in the 1990s. These shell blanks were uniform in anterior thickness and width and smooth-sided, like the Boodie Cave beads. Our experimental work produced bead segments using the two dominant manufacturing techniques observed in Western Australian ethnographies, with 10 beads made using the saw and snap technique and 20 using the percussion technique. One bead was produced from one whole shell, with the posterior end of the shell discarded as the aperture was too small to thread. The saw and snap technique involves resting the whole shell on the flat surface, and making a linear shallow incision at the midpoint of the scaphopod shell with a sharp-edged stone tool. Then, holding the shell with one hand at the posterior portion and the other at the anterior portion, and using the thumbs as a fulcrum point, the shell is snapped in half by pushing away from the maker's body. To make a bead using the percussion technique, the whole shell is placed on a stone anvil with one hand holding the anterior portion. With the free hand a stone knife is used with gentle force applied near the shell midpoint. The point of applied force snaps the shell in half with the posterior portion ricocheting away and the anterior portion remaining on the anvil held by the maker.

The scaphopod shells were photographed at each stage with each fractured end imaged on a Nikon Model LV100ND Pol Research Grade Polarising Microscope, fitted with a Nikon DS-Fi3-L4 camera.

After the beads were made using the two techniques described above, they were threaded on to hemp string. One set of 10 beads was strung using arrangement Style 1 (nested style with the fractured bead end resting against the adjacent bead's anterior end) and the other set of 10 using arrangement Style 2 (concertina style with the anterior bead end resting against the adjacent bead's anterior end) (Figure 6).

The beads were then attached to a purpose-built mechanical wear machine which agitated the beads in a sinusoidal wave for 10 hours. The use-wear machine rotates forwards and then backwards at 300 revolutions per minute and agitates the beads at a velocity of 1.5 agitations per second. The beads were therefore agitated 54,000 times over the 10-hour period. The machine wear would be roughly equivalent to a person wearing the beads as a necklace while carrying out vigorous activity for 10 hours. The experiment ceased at 10 hours, providing a standard number that allows for easy comparison with archaeological specimens. Every 10 minutes that the machine was operating, the beads were soaked in a 10:1 vinegar water mix that contained ochre. This mix simulated dirt and sweat on a human body. After 10 hours of wear the scaphopod beads were photographed with each fractured midpoint imaged on a Nikon Model LV100ND Pol Research Grade Polarising Microscope, fitted with a Nikon DS-Fi3-L4 camera. The use-wear patterns were recorded noting their location on the bead ends (outer edge, inner edge and centre) in addition the type of wear (striations, chipping and polish) and the degree of polish (0%, 1–40%, 41–80% and 81–100%) was recorded.

### Historical collection and archaeological specimen attributes and measurements

Attributes and measurements were recorded from scaphopod beads in historically collected necklaces and archaeological examples from the Pilbara region and the Kimberley to enable comparisons with the Boodie Cave beads and the experimentally made beads.

In 2019, FH visited the Pitt Rivers (UK), British Museum (UK), National Museum of Scotland (UK) and the Western Australian Museum (Australia) to measure and record the Pilbara scaphopod shell necklaces held in these institutions. In addition, photographic images of two necklaces held in the Brighton Museum (UK) and the Horniman Museum (UK) were included in the analysis.

Our analysis also includes necklace data recorded by Goldwyer (2018) for five Kimberley scaphopod necklaces held in the Western Australian Museum. Goldwyer (2018) collected attributes and measurements from scaphopod beads and discarded anterior ends from three archaeological sites on Murujuga, Pilbara and necklace data from historically collected necklaces from the Kimberley held in the Western Australian Museum (Object ID WAM-E04115; WAM-E6602; WAM-E6589; WAM-E4568 and WAM Moya Smith personal collection).

The following attributes were recorded for each historically collected scaphopod necklace: (1) strand length (cm); (2) necklace type (necklace, bracelet, string, bead); (3) number of strands; (4) total length (cm); (5) number of beads; (6) wear (present, absent); (8) fibre type (animal, plant); (9) fibre spin type (hand, machine); (10) string colour; (11) string number; and, (12) stringing type (Style 1, Style 2).

A range of measurements were recorded from the 27 scaphopod beads from Boodie Cave, the 30

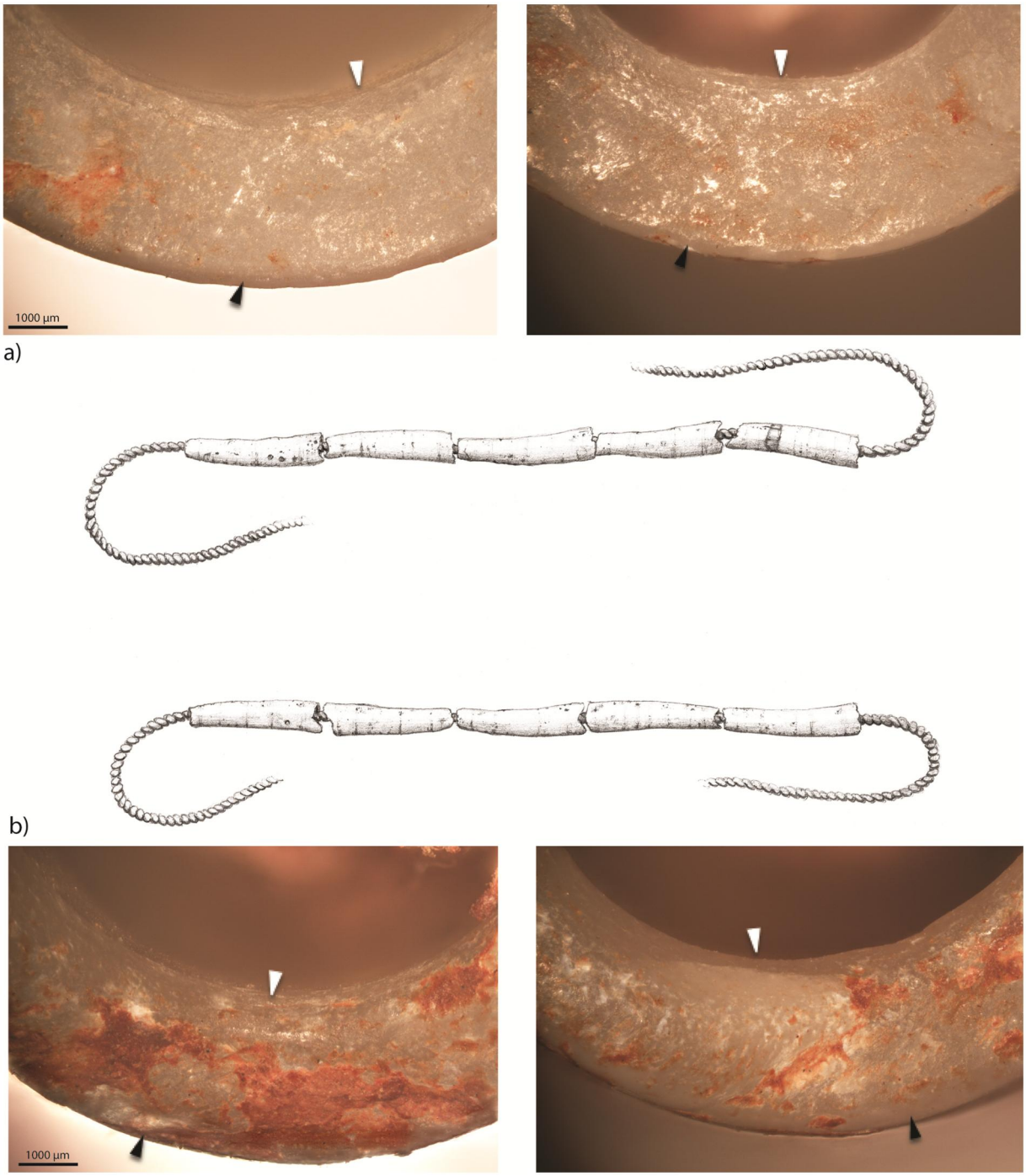


**Figure 6.** Experimental scaphopod beads after 10 hours of mechanical wear, strung in two arrangements: (a) Style 1 the use-wear evident shows minimal polish on inner edge (white arrow) and some polish on outer edge (black arrow) of the bead as the beads nest one inside the other agitating the outer lip of the bead more than inner edge of the bead; and, (b) Style 2 use-wear shows rounding and polish on both inner (white arrow) and outer (black arrow) edge of the bead as the beads agitate against each other with full contact of all surfaces of the bead resulting in the rounding and high degree of polish (image by Fiona Hook and Adam Black).

experimentally made beads, 55 beads from international and WAM museum collections. Measurements and attributes were also recorded by FH on the archaeological Kimberley scaphopod beads reported by Balme et al. (2018) using the images provided in their paper. All measurements on physical beads were made using Mitutoyo (CD-6″ CX) digital callipers with the jaws covered in a layer of rubber ('Tool Magic') to prevent damage. The scaphopod bead measurements and attributes (including those taken from published images) included: (1) morphological features present (anterior, posterior, none); (2) overall length (mm); (3) anterior width (mm); (4) midpoint width (mm); (5) posterior width (mm); (6) posterior shell thickness (mm); (7) break type (concave, straight, angular, stepped, jagged, longitudinal);

(8) nested bead fragment wedged inside larger bead; (9) broken bead morphological features (anterior, posterior, none); and, (10) anterior damage (even, chipped, jagged, wavy).

Each bead was imaged using a Canon digital SLR camera. The fractured end was imaged using either a Dino-Lite Edge AM4115ZT digital microscope or a Nikon Model LV100ND Pol Research Grade Polarising Microscope, fitted with a Nikon DS-Fi3-L4 camera. Microscopy allowed the following to be recorded for each bead: (1) degree of wear on bead ends (0%, 1–40%, 41–80%, 81–100%); (2) wear type (striations, chips, polished, none); and (3) wear position (interior, exterior, centre, none).

## Results

### *Experimental dataset*

Our experimental work produced bead segments using the two dominant manufacturing techniques (percussion and saw and snap) observed in use in Western Australia, with each technique producing distinctive breakage patterns. During the experimental work, 10 beads were made using the saw and snap technique and the other 20 using direct percussion with a stone flake resting on a stone anvil. Of those beads broken using the saw and snap technique, all produced a straight break (Figures 7 and 8a). The beads made using the percussion technique instead resulted in 11 concave, two angular, one jagged and six straight edges (Figures 7 and 8b). These breakage patterns were compared to the archaeological specimens. The experimental beads range in size from 33.83 to 15.77 mm in length, with a median length of 23.33 mm. The anterior ends have a median width of 5.04 mm (range = 4.14–5.79 mm) and the ends have a median width of 3.9 mm (range = 3.21–4.91 mm). The percussion beads manufacture technique resulted in a median of 1.5 posterior/medial fragments.

Predictably, the different arrangements and points of contact between the adjacent shell fragments produced different and directly observable use-wear patterns. Scaphopod beads are tapered and can be strung in a nested fashion where they sit one inside the other (Style 1), or they are strung with the tapered ends resting against each other (Style 2) (Figure 6). In the case of Style 1, the bead fractured ends exhibit polish predominantly on the outside edge with the polished surface less than 40% of the edge (Figure 6a). In contrast, Style 2 bead fracture ends have a high degree of polish on the outside edge and inside lip with the polished surface area covering some 41–80% of the edge (Figure 6b).

### *Museum collections*

Of the six scaphopod necklaces inspected in the United Kingdom, three are strung on hand-made plant fibre, with only two showing signs of use-wear (see Table 1; Figure 9). The necklace held in the British Museum (Oc1896-.1035) was collected by Clement in 1896. This necklace has worn beads (41–80%) which are stained by soil and are strung on a thick hand-spun plant fibre (Figure 9). The necklace held in the Western Australian Museum (WAM-E00635) is strung on a hand-made plant

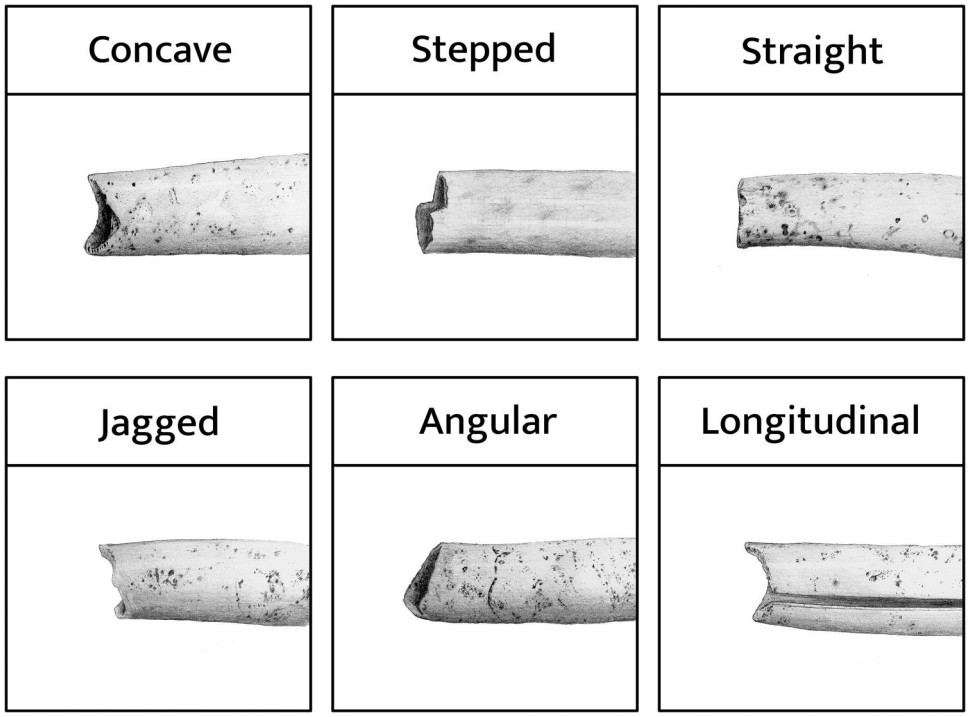


**Figure 7.** Scaphopod bead (anterior portion) midpoint break types (image by Adam Black).

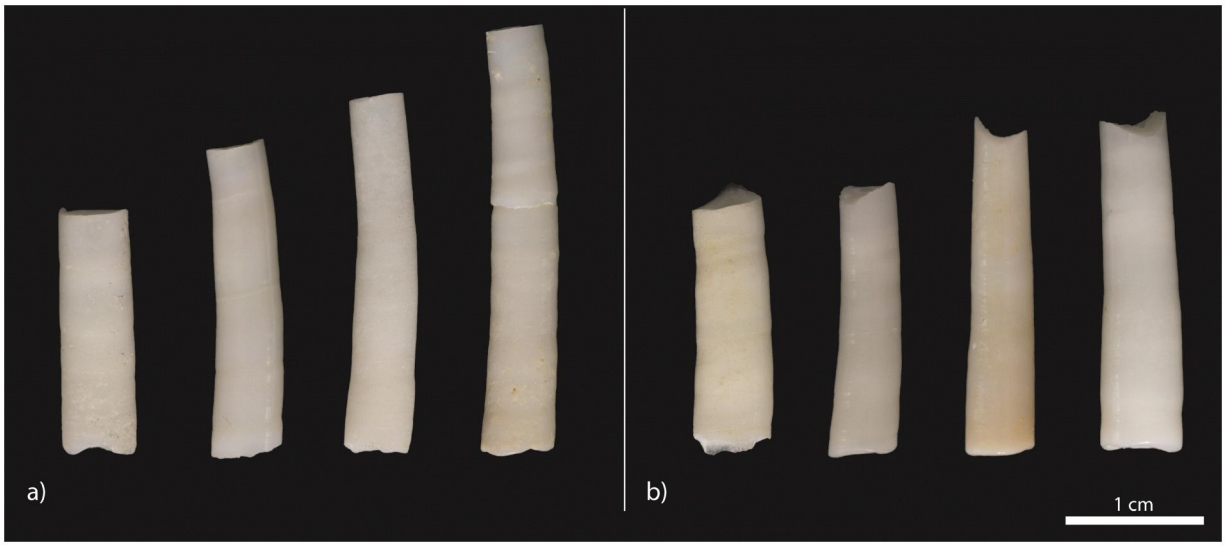


**Figure 8.** Examples of experimental scaphopod beads manufactured using the: (a) saw and snap technique; and, (b) percussion technique (image by Fiona Hook).

fibre with the beads showing some degree of wear (1–40%). The four scaphopod bead necklaces viewed in the Pitt Rivers (UK) and the National Museum of Scotland (UK) had no visible use-wear and are strung on machine-made plant fibres (Figure 9). It is possible that these necklaces were made to sell to collectors, providing revenue for Aboriginal people to have access to European goods in the late nineteenth century (Konishi and Paterson 2021:129). One of the necklaces held by the National Museum of Scotland (A.1898.372.55) is mentioned in Clement and Schmeltz (1903) (Figure 5).

The nine necklaces collected from the Pilbara region all have multiple strands, except for the WAM necklace which comprises one long strand with two loops at either end. The number of strands ranges from three to seven with the length of the necklace averaging 43 cm (Table 1). The necklaces recorded in the museum and contemporary collections were rarely strung haphazardly, indicating that the makers designed necklaces with specific features and aesthetics in mind. Most beads were threaded using Style 1 (nested – anterior end abutting a fractured end). On average there are 2,975 beads per necklace. The beads range in length from 6.3 mm to 23.6 mm with a median length of 13.8 mm. Of the 55 beads measured, 54 are anterior portions. The beads are all smooth sided, often glossy, and some have visible transverse growth lines (Figures 5 and 9).

Eight of the nine Pilbara scaphopod necklaces held in museums have been strung in a nested fashion (Style 1). The wear patterns observed on two of the historical specimens show that nested stringing results in high polish on the outer edge of the fractured end as it sits inside the anterior portion of the adjacent bead (Figure 9a). Polish is also observed on the inside edge of the bead owing to rubbing along the string with some rounding of the whole edge.

Our observations from the historical collections and experimental wear trial is that Style 1 necklaces sometimes result in the fractured ends of beads becoming wedged inside the anterior portion of the adjacent bead. During wear, the angle of the beads can result in small sections of the anterior portion being broken off producing small beads of 2 mm in length. It could be that the small sections of beads observed by Balme et al. (2018) from the Kimberley archaeological sites are the result of this attritional wear pattern through time. Furthermore, and as experienced by the experimental scaphopod bead makers in Europe and the Middle East, making small beads of less than 3 mm is difficult and requires a specific technique that is not observed in the Australian historical or archaeological record (Campbell 2017).

### *Archaeological beads from Boodie Cave*

The 26 beads available for analysis are anterior portions which have evidence for breakage at the midpoint of the shell. One bead (J08-100-B010) was submitted for dating prior to this analysis and, therefore, is not included. The absence of posterior portions indicates that these beads have been transported to the site having been made elsewhere, as the posterior ends have an aperture too small to thread. The anterior bead end edges are rounded with notches present on some specimens. These notches are present in beach collected whole scaphopod specimens used in the experimental analysis (Figure 8). The anterior ends have a median width of 4.45 mm (range = 3.40–4.86 mm). The beads range in size from 22.8 mm to 7.4 mm long with a median length of 17.3 mm and median weight of 0.33 g (range = 0.07–0.74 g). The broken bead ends have a median width of 3.91 mm (range = 2.64–4.40 mm) (Table 2).

**Table 1.** Pilbara scaphopod necklaces held in museum collections.

| Museum | Museum object accession number | Museum named collection place | Museum named collection indigenous group | Museum named collection collector | Use-wear | Fibre | Strands ($n$ =) | Style | Necklace hanging length (cm) |
|---|---|---|---|---|---|---|---|---|---|
| Pitt Rivers | 1898.75.67 | | | | no wear | linen | 3 | 1 | 40 |
| Pitt Rivers | 1898.75.68 | | | | no wear | cotton | 3 | 1 | 50 |
| British Museum | Oc1896,.1035 | Cossack /Hamersley Plateau | Ngarluma | Clement, E | wear | plant | 4 | 1 | 90 |
| Brighton Museum | WA501694 | Sherlock River | Kariyarra | Clement, E | | | Not viewed | | |
| Hornimon | 25.11 | | | Clement, E | unknown | cotton | 6 | 1 | 45 |
| National Museum of Scotland | A.1896.346.3 | Cossack | Ngarluma, Yindjibarndi | | no wear | cotton | 6 | 1 | 40 |
| National Museum of Scotland | A.1898.372.55 | Balla Balla | Ngarluma/Kariyarra | Clement, E | no wear | jute, ochre | 4 | 1 | 40 |
| National Museum of Scotland | A.1923.734 | Roebourne | Ngarluma | | On display | | 6 | 1, 2 | 40 |
| Western Australian Museum | E0635 | Roebourne | Ngarluma | Speight, A | wear | plant | 5 | 1 | 90 |

All beads are smooth-sided, often glossy, and some have transverse growth lines (Figure 10). Twenty-two of the 26 beads have concave broken ends with the remainder either angled or straight (Figures 7, 10 and 11).

All broken bead ends exhibit polish and some rounding (Figure 12). Sixteen beads have evidence for polish and rounding on the broken bead end's inner lip, outer edge, and bead end. Four have polish on the outer edge and broken surface, four on the outer edge and one has polish only on the bead's inner lip and one on the bead end, only. Using the experimental results, all 26 scaphopod beads exhibit edge polish and rounding consistent with their use as strung beads in Style 2

## Discussion

The Boodie Cave scaphopod bead assemblage significantly expands our knowledge of Terminal Pleistocene-Early Holocene-aged ornaments in northwest Australia. The assemblage of scaphopod beads is the first to be described in detail from the Pilbara region using experimental analysis. This information allows for a more detailed analysis of bead manufacture characteristics and use-wear morphology alongside a regional comparison between the Pilbara and the Kimberley to investigate symbolic behaviours.

### *Evidence for manufacture*

Our experimental archaeology program revealed that shallow notching at the broken bead end is the result of the percussion manufacturing method used by the bead maker (Figures 7 and 11) and is not use-wear resulting from bead stringing (contra Balme and O'Connor 2017:11–12). The percussion technique manufacture is the most efficient and least-effort method, which is advantageous given the large numbers of beads required for necklaces as indicated in the historical collections and the Enderby Island manufacturing site at Murujuga. Kimberley Aboriginal women produce scaphopod beads today by laying the shells on an anvil and breaking them with a stone knife. The archaeological evidence, supported by the experimental work, indicates that scaphopod beads have been made for tens of millennia using the same technique in Australia's northwest (Figure 13).

Ten of the published southern Kimberley beads have longitudinal breaks and seven have large, stepped notches (Balme et al. 2018). The Boodie Cave and Murujuga beads; however, do not have these same types of damage. While Goldwyer (2018) demonstrated that longitudinal breaks may be the

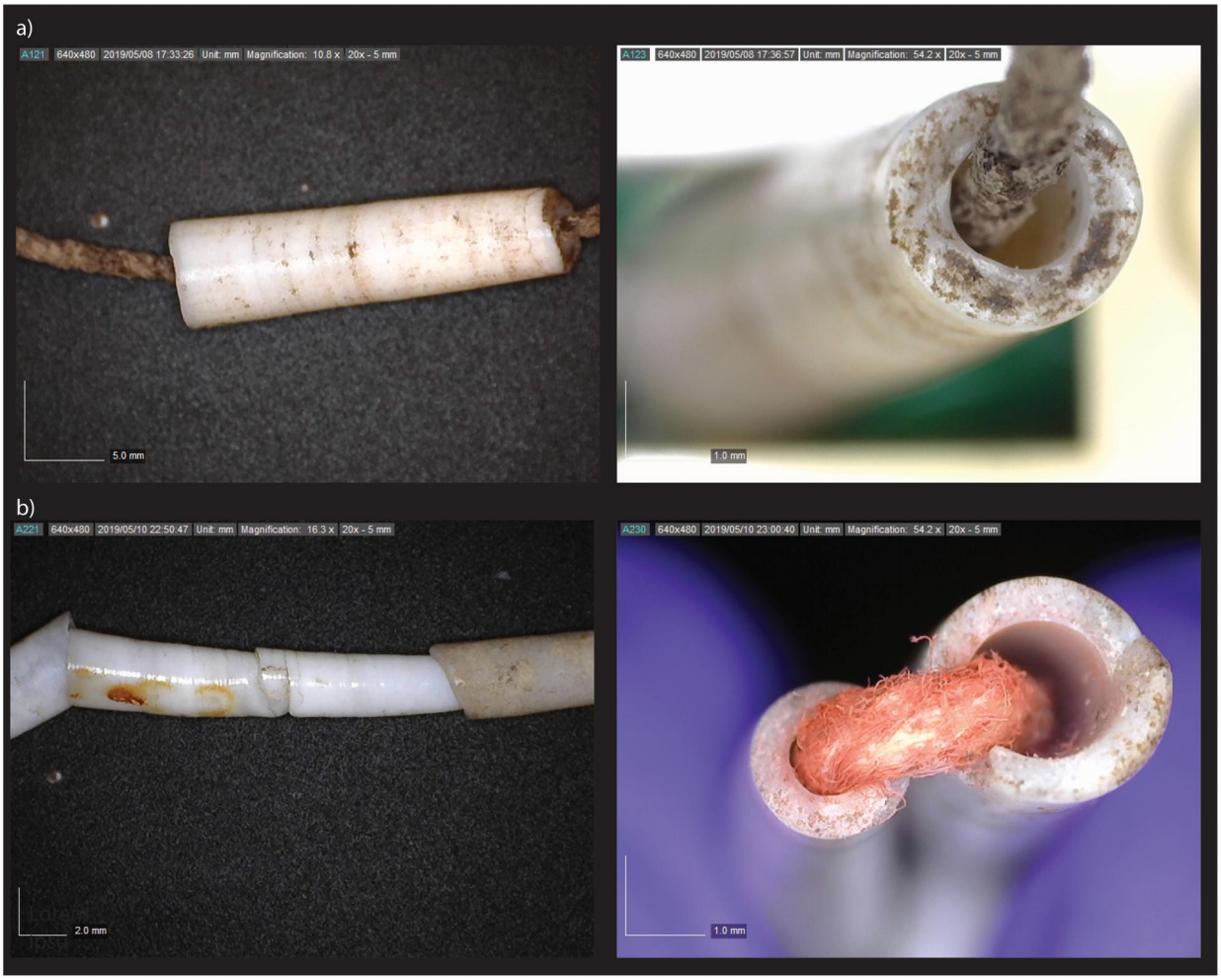


**Figure 9.** Scaphopod beads and microscopy of bead fractured ends from scaphopod necklaces: (a) bead end with polish and rounding collected by E. Clement from Cossack and held in the British Museum (Oc1896-.1035); and, (b) bead ends with no use-wear collected by E. Clement from Balla Balla and held in the National Museum of Scotland, Edinburgh (A.1898.372.55). (Image by Fiona Hook)

result of trampling, the deep notches seen in the Kimberley beads were not produced in his trampling experiments nor in the use-wear experiments. As such, further trampling experiments are needed to explore how this process may affect this long form of shell bead and if indeed the notches seen in the Kimberley beads are the result of post-depositional processes. In addition, microscopic analysis of the longitudinally broken and deeply notched beads may assist in determining how these beads were made or broken once discarded.

Finally, during experimental work on the manufacture of the beads for his research, Goldwyer (2018) adopted the same techniques used by FH, MCL, and SU in 2017 to test whether scaphopod fragments from the Murujuga site were produced during bead manufacture and if there was evidence for in situ tusk shell bead manufacture. Goldwyer (2018) determined that the significantly high number of posterior fragments at Enderby 10 on Enderby Island was evidence for this site being a scaphopod bead manufacturing locale. He also determined that the direct percussion technique was used for breaking the beads. Goldwyer's (2018) study included a trampling experiment to investigate the archaeological signature of scaphopod fragmentation within a general midden context but did not produce the same types of break patterns seen in either the Enderby 10 or Boodie Cave scaphopod beads.

### *Bead size and shape comparisons*

The scaphopod beads collected historically from the Kimberley are the largest beads recorded in this analysis, with a median length of 19.64 mm (Table 3; Figure 14). In this study, the Boodie Cave beads are some of the largest recovered from an archaeological context, with a median length of 17.3 mm. The 55 southern Kimberley beads from Riwi, Carpenter's Gap 1 and 3, Windjana Gorge 1, and Mount Behn (Balme and O'Connor 2017; Balme et al. 2018), range in length from 2.7 mm to 23.8 mm. The Riwi beads have a median length of 12.5 mm. The median anterior width of the Riwi beads is 3.6 mm compared with the 4.45 mm from Boodie Cave. The Murujuga beads are the smallest

**Table 2.** Boodie Cave scaphopod artefact morphometrics.

| Bead ID | Square | SU | Overall length (mm) | Width 1 (mm) | Width 2 (mm) | Width 3 (mm) | Break type |
|---|---|---|---|---|---|---|---|
| J08-100_B001 | A103 | 3 | 13.26 | 4.24 | 4.20 | 4.02 | ST |
| J08-100_B002 | A103 | 5 | 12.15 | 4.27 | 4.12 | 3.17 | CV |
| J08-100_B003 | A103 | 5 | 13.36 | 3.44 | 3.24 | 2.64 | AN |
| J08-100_B004 | F101 | 5 | 22.80 | 4.76 | 4.47 | 4.28 | CV |
| J08-100_B005 | F101 | 5 | 20.19 | 4.72 | 4.39 | 4.05 | CV |
| J08-100_B006 | F101 | 5 | 18.72 | 4.53 | 4.32 | 3.96 | CV |
| J08-100_B007 | F101 | 5 | 14.97 | 4.48 | 4.35 | 4.40 | CV |
| J08-100_B008 | F101 | 5 | 15.28 | 4.86 | 4.57 | 4.36 | CV |
| J08-100_B009 | G101 | 5 | 7.40 | 3.49 | 3.33 | 3.18 | CV |
| J08-100_B010* | G101 | 5 | Dated before analysis occurred | | | | |
| J08-100_B011 | G101 | 5 | 16.91 | 4.34 | 4.2 | 4.08 | CV |
| J08-100_B012 | G101 | 5 | 15.88 | 4.34 | 4.19 | 3.96 | CV |
| J08-100_B013 | G101 | 5 | 18.93 | 4.64 | 4.18 | 3.48 | CV |
| J08-100_B014 | G101 | 5 | 21.20 | 4.72 | 4.46 | 3.93 | AN |
| J08-100_B015 | G101 | 5 | 19.62 | 4.64 | 4.40 | 3.91 | CV |
| J08-100_B016 | G101 | 5 | 18.48 | 4.50 | 4.15 | 3.90 | CV |
| J08-100_B017 | G101 | 5 | 17.56 | 4.71 | 4.46 | 4.21 | CV |
| J08-100_B018 | G101 | 5 | 19.48 | 4.75 | 4.27 | 4.15 | CV |
| J08-100_B019 | G101 | 5 | 15.74 | 4.48 | 4.09 | 3.8 | CV |
| J08-100_B020 | G101 | 5 | 13.62 | 4.41 | 4.1 | 3.65 | CV |
| J08-100_B021 | G101 | 5 | 17.73 | 4.16 | 3.86 | 3.77 | CV |
| J08-100_B022 | G101 | 5 | 18.65 | 4.27 | 3.95 | 3.61 | CV |
| J08-100_B023 | G101 | 5 | 16.51 | 4.35 | 3.87 | 3.65 | CV |
| J08-100_B024 | G101 | 5 | 16.97 | 4.58 | 4.1 | 4.14 | AN |
| J08-100_B025 | G101 | 5 | 20.4 | 4.29 | 3.92 | 3.74 | CV |
| J08-100_B026 | G101 | 5 | 19.03 | 4.11 | 3.92 | 3.62 | CV |
| J08-100_B027 | G101 | 5 | 14.20 | 3.40 | 3.38 | 3.30 | CV |

Key: * = sampled for dating; Bead size: Width 1 = anterior (thicker end), width 2 = middle of bead, width 3 = fractured end (thinner end); Break type = CV – Concave, ST – Straight, AN – Angled, JA – Jagged.


**Figure 10.** Sample of Boodie Cave scaphopod beads from square G101 and A103 (image by Fiona Hook).

and are closest in size to those from Mt Behn in the southern Kimberley. Overall, the southern Kimberley beads recovered from archaeological contexts are smaller than those recovered from Boodie Cave.

Based on aperture width of archaeological and museum samples, scaphopods of a specific size were being collected from the coast. The 42 scaphopod species known to occur in the northwest have anterior apertures ranging in size from 0.5 mm to 18.1 mm (Lamprell and Healy 1998); however, the range in anterior aperture size for the archaeological and museum beads is much narrower, ranging from 1.3 mm to 6.7 mm, indicating cultural selection processes as most of the species used to make many of the beads occur in both regions.

The length/width ratio data for the archaeological bead assemblages from Boodie Cave, Murujuga, and the southern Kimberley clearly shows three separate populations (Figure 15). The Kimberley scaphopod shell beads are made from slightly smaller-sized scaphopods resulting in smaller beads. The observation by Balme and O'Connor (2017) that the Riwi scaphopod shell beads have been curated, owing to the worn nature of the bead ends and their smaller length, is supported by both the experimental data and the beads from Boodie Cave. The fact that the beads in the Kimberley and Pilbara have similar aperture widths hints at a cultural tradition as the size of the beads is controlled by manufacture and species selection. More samples will help determine if this trend is indeed a tradition.

In terms of morphology, all bar one of the beads recorded from Boodie Cave, Murujuga, the southern Kimberley, and the historical collections were made from smooth-sided scaphopods. Most have a gentle taper, transverse growth lines, and anterior aperture widths ranging from 3.4 to 6.6 mm. Of the 42 scaphopod species that occur off the northwestern Australian coast, eight species fit these characteristics: *Laevidentalium leptosceles*, *L. erectum*, *L.*

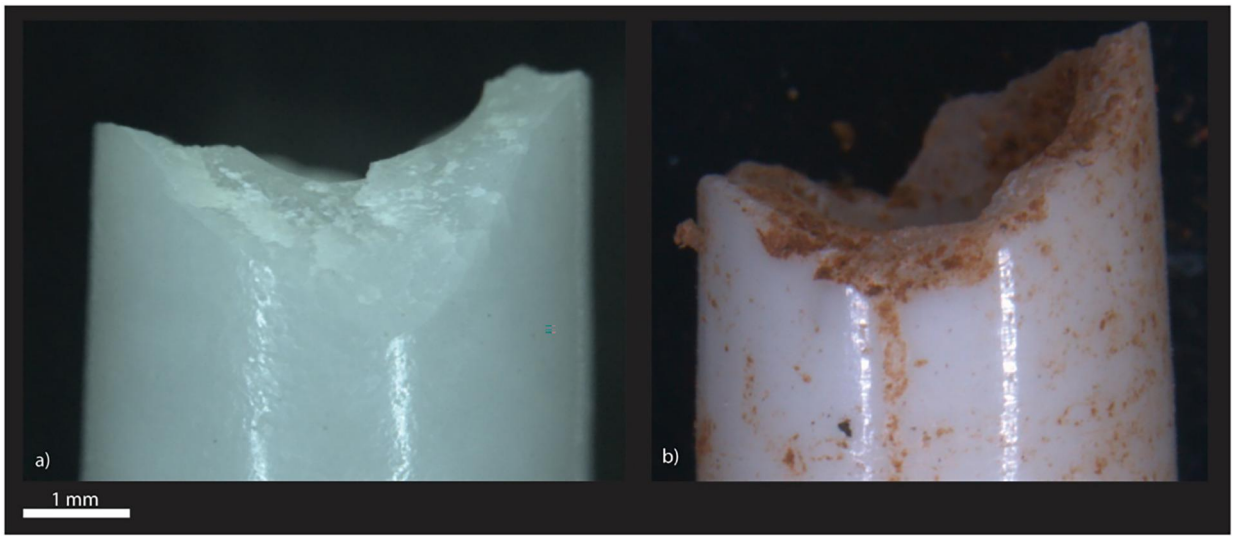


**Figure 11.** Bead percussion characteristics: (a) experimental bead (EXP-B021) concave break; and, (b) Boodie Cave bead (J08-100_B011) concave break (image by Fiona Hook).

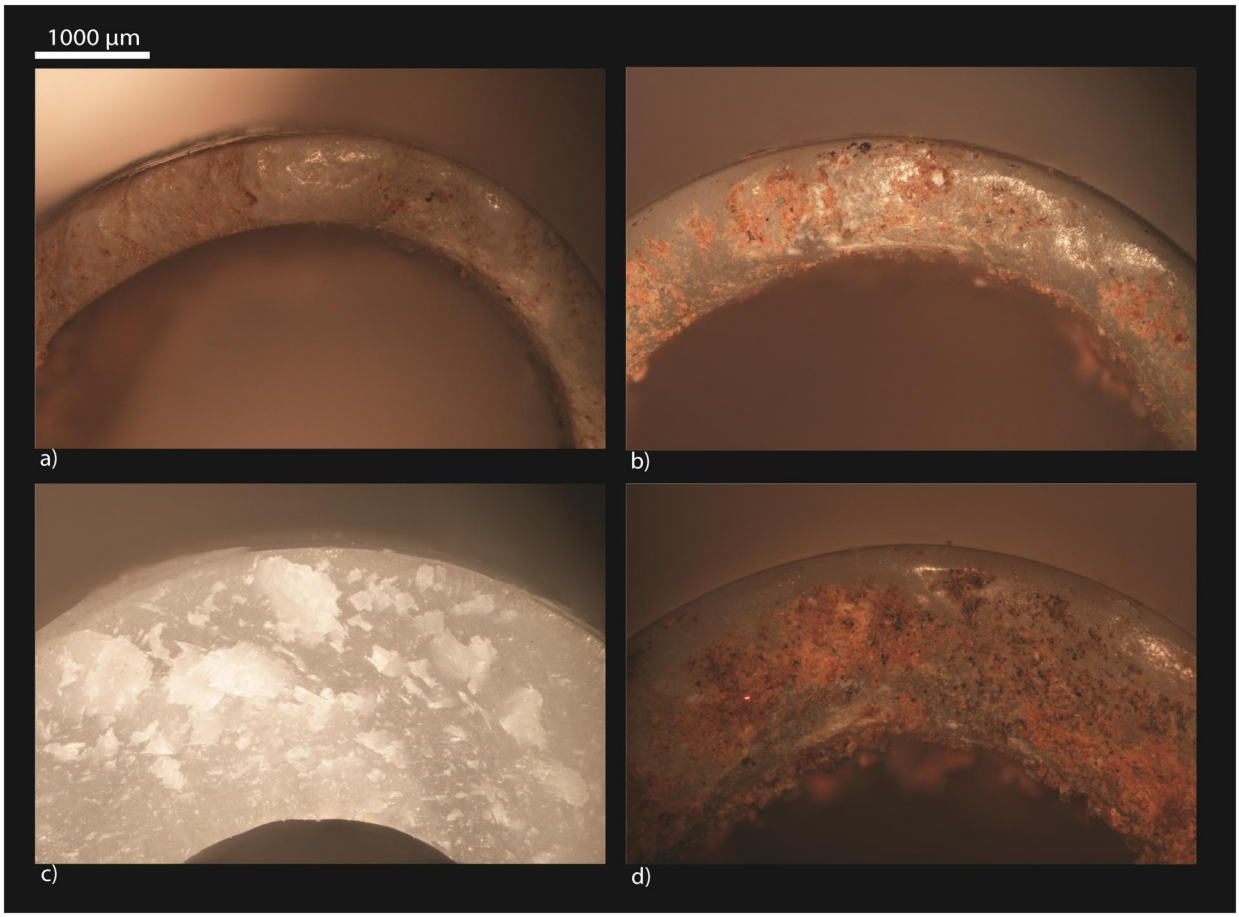


**Figure 12.** Boodie Cave scaphopod shell beads. (a, b and d) Boodie Cave beads with polish and rounding on bead end; and, (c) freshly made experimental bead with no use-wear (image by Fiona Hook).

*marshae*, *L. martyi*, *L. lubricatum*, *Antalis longitrorsa*, *Fustiaria stenoschiza* and *Calliodentalium crocinum* (Lamprell and Healy 1998). Three of these species: *L. marshae*, *L. martyi* and *L. lubricatum*, occur in both the Kimberley and the Pilbara. *L. lubricatum* has the highest number of collection locations perhaps suggesting that this species is one of the most common in northwest Australia (Lamprell and Healy 1998:120). *L. lubricatum* is the species identified for the bead manufacture on Enderby Island, Murujuga (Goldwyer 2018; McDonald et al. 2023a, 2023b, 2023c) and it may be that *L. lubricatum* is the preferred species that was targeted by Aboriginal people in the past based on the similarities of size and shell smoothness. *L. lubricatum* has one of the largest anterior apertures (6 mm) as well as a low number of transverse growth lines which has been observed in most of

the archaeological and historical specimens inspected. Aboriginal peoples historically collected scaphopod shells from beaches, where we presume the full range of scaphopod species would be available; however, from the archaeological and historical datasets people targeted a specific narrower range of species, based on scaphopod size and smoothness. To further this avenue of inquiry, it might be useful to investigate species variability using DNA analysis on scaphopod shells from archaeological sites and historical sites (Martin et al. 2021).

Balme and O'Connor (2017) suggest that the most parsimonious explanation for the smaller Kimberley bead size is that near the coast beads are recirculated for less time and replaced more readily than inland counterparts given the greater ease of access to shorelines. The Boodie Cave beads may have been worn by the same person who collected the shells from the beach, whereas the inland Kimberley examples were almost certainly traded down-the-line and thus had a much longer 'use life' and possibly additional ceremonial and ritual values within the desert trade systems (Akerman 2009; Meggitt 1962). These desert trade systems stretched across the western side of the continent and included the production of baler and pearl shell pendants. This same explanation cannot be used at Murujuga – where the manufacturing site is only 3–5 km from the beaches where the shells were probably collected. Here it would appear that much smaller beads were the desired product.

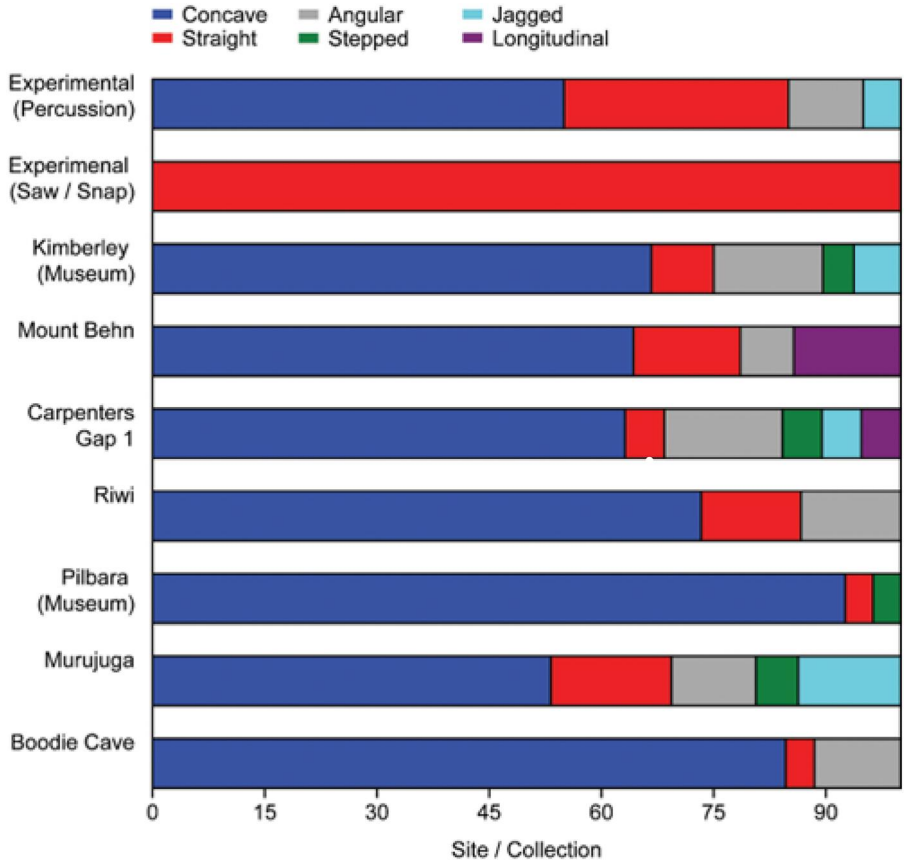


**Figure 13.** Scaphopod bead midpoint break types by site/collection/experimentation (data for Carpenter's Gap 1, Riwi and Mount Behn from Balme and O'Connor (2017) and Balme et al. (2018); data for Murujuga from Goldwyer (2018).

**Table 3.** Scaphopod bead length and anterior bead end aperture width (data for Carpenter's Gap 1, Riwi and Mount Behn from Balme and O'Connor (2017) and Balme et al. (2018); data for Murujuga from Goldwyer (2018).

| Size (mm) | Boodie Cave | Murujuga | Pilbara (Museum) | Riwi | Carpenters Gap 1 | Mount Behn | Kimberley (Museum) |
|---|---|---|---|---|---|---|---|
| Length maximum | 22.8 | 15.1 | 23.6 | 17.6 | 22.1 | 12.6 | 32.7 |
| Length minimum | 7.4 | 2.6 | 6.3 | 5.2 | 2.7 | 4.2 | 6.3 |
| Length median | 17.3 | 6.5 | 13.8 | 12.5 | 9.9 | 7.5 | 19.6 |
| Length measurements ($n$ =) | 26 | 15 | 55 | 10 | 15 | 5 | 48 |
| Aperture width maximum | 4.9 | 3.5 | 6.7 | 4.6 | 4.0 | 4.9 | 4.9 |
| Aperture width minimum | 3.4 | 1.9 | 1.3 | 2.0 | 2.4 | 2.7 | 2.7 |
| Aperture width median | 4.4 | 2.8 | 3.3 | 3.7 | 3.2 | 3.8 | 4.0 |
| Aperture measurements ($n$ =) | 26 | 10 | 54 | 10 | 11 | 11 | 46 |

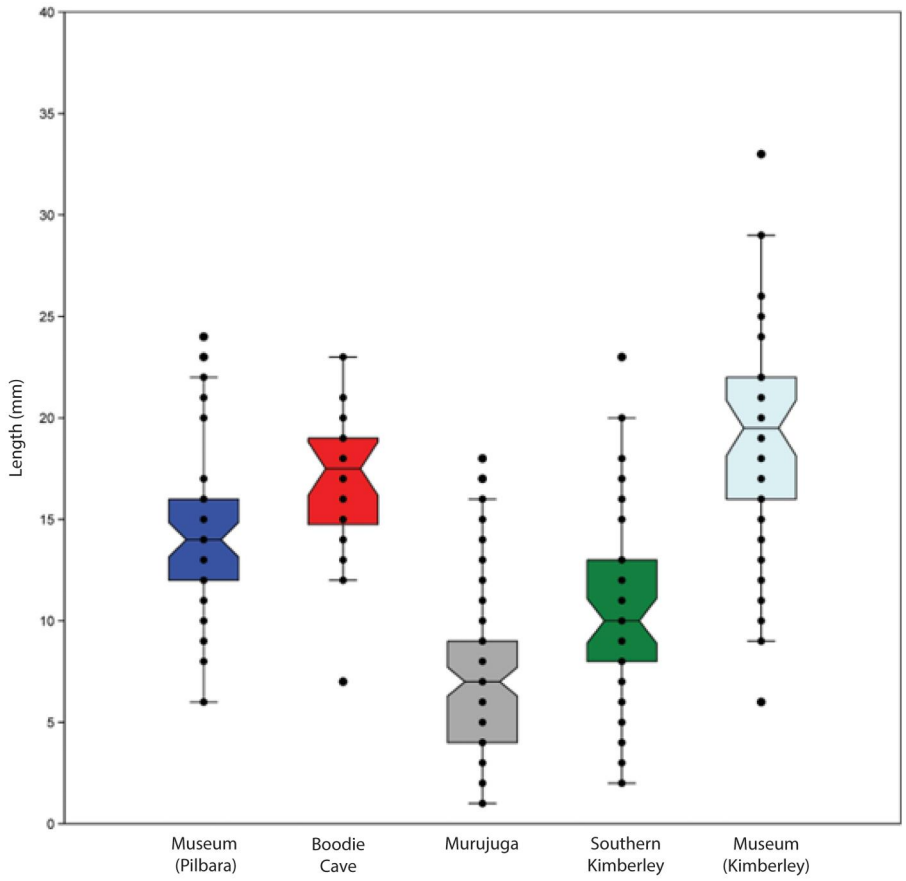


**Figure 14.** Scaphopod bead median size ranges by site/collection. Data from southern Kimberley derived from Balme and O'Connor (2017) and Balme et al. (2018); data for Murujuga from Goldwyer (2018).

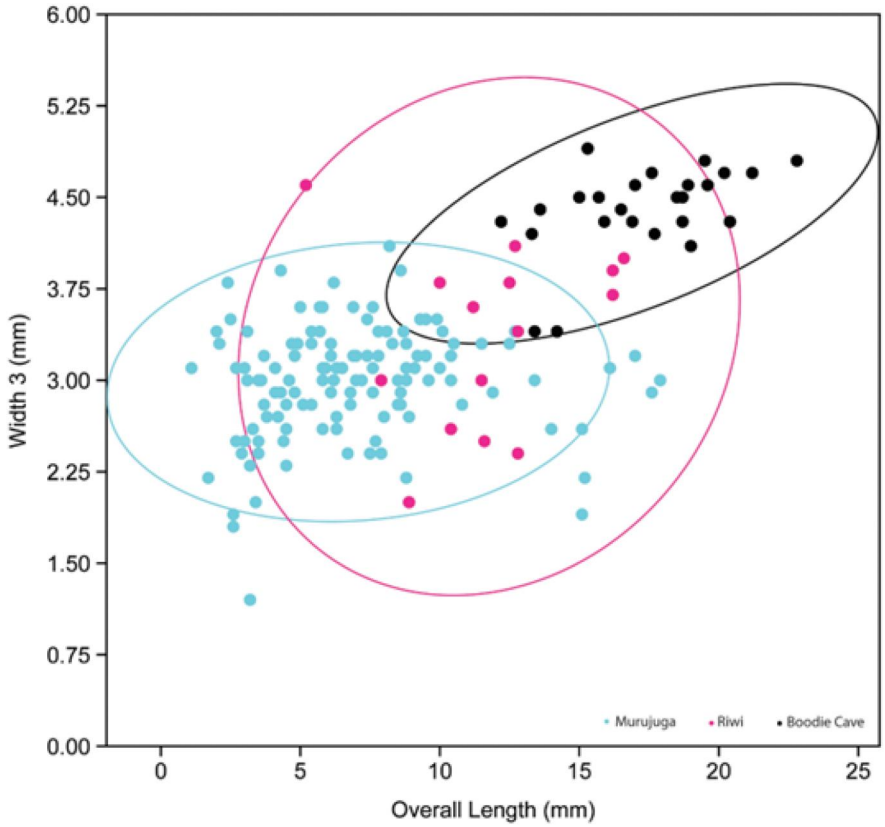


**Figure 15.** Scaphopod bead aperture width vs length by site/collection (with 95% fit ellipses).

### *Stringing style*

The Boodie Cave beads have polish and rounding consistent with being strung into Style 2 necklaces, while the amount of polish is in the 81–100% category. The use-wear experiment indicates this level of polish equates to at least 10 hours of vigorous agitation. Only two of the historical necklaces collected from the Pilbara had beads that displayed use-wear, and both were threaded in Style 1 and display polish in the 1–40% category. Indeed, all necklaces in the historical collections have beads threaded in Style 1. Interestingly, the single bead at Wadjuru Pool, to the south of Rosemary Island at Murujuga, has wear on the outside rim suggesting it was also strung in Style 1 (Stephenson 2016). Further microscopic analysis of the beads from the southern Kimberley, Cape Range, and Murujuga is needed to allow for comparison of regional and/or temporal changes in necklace threading styles, however, the Boodie Cave beads are currently the only ones identified as having been strung in Style 2.

Given the thousands of beads in the historical necklaces from museum collections, the number of scaphopod shell beads in Australian archaeological sites is surprisingly low. If the historically collected examples are representative of a continuing tradition, then over 2,000 beads would be a reasonable estimate per necklace. The generally low number of scaphopod shell beads recovered from archaeological sites – apart from the production site on Murujuga (McDonald 2023a) – suggests that necklaces may have been produced with less beads than those observed in museum collections, or, that the beads were heavily curated. Furthermore, we must not forget the impact of taphonomy, sampling, and under-recognition. Balme and O'Connor (2017:16) suggest that the southern Kimberley beads were 'likely worn in secular rather than sacred contexts' owing to their discard in general habitation sites rather than in restricted secret locations where they may have been associated with sacred or ceremonial practices. Similarly, focused research on trade beads in the Northern Territory also demonstrates this miniscule-sized evidence for symbolic behaviour may well be overlooked by archaeological excavations which have not used small mesh-sizes (Litster et al. 2018).

The bead manufacturing site (MLP-EI010) on Enderby Island, Murujuga (squares 562910 and 562910B) provides evidence for the mass manufacture of scaphopod beads in the Late Holocene (McDonald 2023a). The 1 m x 0.5 m excavation square contained 851 posterior scaphopod ends and only six anterior ends, showing that 857 beads were made at this site. The very small size of the sampled deposit (0.5 $m^2$) from a midden covering several hectares suggests that many thousands of beads may have been made in the locality. The fact that scaphopod beads were recovered from three other sites across the archipelago (Goldwyer 2018; McDonald 2023a, 2023b, 2023c), again in very small sample squares, indicates that this form of archaeological evidence is a ubiquitous record which we have only just begun to understand.

## Conclusions

The unique terminal Pleistocene assemblage of beads from Australia's northwest coast and comparison with archaeological and historical collections provide insights into the long-term production and use of scaphopod shells for beads in the Australian context. Our experimental work demonstrates that the Boodie Cave shell beads were made using the percussion technique, a method still used today by Aboriginal people in the Kimberley. Perhaps most interestingly, the Boodie Cave beads were strung with their narrower apical ends and wide ends alternating against each other, rather than nested in concatenated style as seen in historical examples from the Kimberley and Pilbara. This patterning may represent a regional variation in display and technological organisation, though further work is required to compare the microscopic bead use-wear and to further investigate the regional and temporal changes in necklace styles suggested by this research.

Shell bead discard in Boodie Cave is dated to the Terminal Pleistocene–Early Holocene when the sea was over 20 km away. These beads were probably produced on the original and now-drowned coastline before being transported, traded, or indeed worn, by individuals whose territory included the productive coastal zones of the Pleistocene northwest shelf and the rich subcoastal areas of these coastal deserts. They provide early and additional evidence for the trade, wearing, and loss of scaphopod beads by mobile hunter-gathers travelling from a nearby coastline.

## Acknowledgements

Archaeological excavations at Boodie Cave were part of the Barrow Island Archaeological Project (BIAP) funded by an ARC Discovery Grant (DP130100802) award to Peter Veth, 2013-2017 Chief Lead Investigator and recent research has been conducted under ARC Desert People: Australian Perspectives (DPP) Laureate Project (FL220100046) awarded in 2022 to Peter Veth. We acknowledge the contributions of all researchers and managers who were part of BIAP and who are part of DPP.

The authors would like to acknowledge the information and images provided by Kim Akerman for the Kimberley. We would like to acknowledge the contributions of Alistair Paterson who provided Fiona Hook with the list of scaphopod necklaces held in overseas museums

and for assistance with contacting those museums to arrange site visits; Chris Butler built the experimental bead use-wear machine; Richenda Prall provided the ochre for the experimental work; and Merv Cooper for providing the *Laeverdentalium lubricatum* specimens for the experimental work. Adam Black prepared the drawings in Figures 1, 6, and 8.

Fiona Hook would like to thank the curators at Pitt Rivers (UK), British Museum (UK), National Museum of Scotland (UK) and the Western Australian Museum (Australia) for allowing access to their collections. Fiona Hook would like to acknowledge the assistance of the curators of the Brighton Museum (UK) and the Horniman Museum (UK) for providing additional photographs of the necklaces in their collections. Jo McDonald would like to acknowledge the permissions granted by the Murujuga Aboriginal Corporation's Circle of Elders to the Murujuga Dynamics of the Dreaming ARC Linkage Project (LP140100393), who granted original permissions for the excavations at Enderby Island and the research project undertaken by Wade Goldwyer, with the results more fully published in the cited references.

We also thank the reviewers and the *AA* editors for their helpful comments and suggestions.

## Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Funding

This research was supported by the Australian Research Council: (1) Discovery Outstanding Researcher Award (DP130100802) Barrow Island Archaeology Project; (2) Linkage Project Murujuga Dynamics of the Dreaming (LP 140100393); (3) Desert People: Australian Perspectives (DPP) Laureate Project (FL220100046); and (4) Centre of Excellence for Australian Biodiversity and Heritage (CE170100015).

## ORCID

Fiona Hook http://orcid.org/0000-0001-5025-4293
Michelle C. Langley http://orcid.org/0000-0002-0299-5561
Sean Ulm http://orcid.org/0000-0001-6653-9963
Jo McDonald http://orcid.org/0000-0002-2701-7406
Peter Veth http://orcid.org/0000-0002-1717-6390

## References

Akerman, K. 2009 Aboriginal baler shell implements from north west Australia. *Mankind* 10(1):16–19.

Balme, J., I. Davidson, J. McDonald, N. Stern and P. Veth 2009 Symbolic behaviour and the peopling of the southern arc route to Australia. *Quaternary International* 202(1–2):59–68.

Balme, J. and K. Morse 2006 Shell beads and social behaviour in Pleistocene Australia. *Antiquity* 80(310): 799–811.

Balme, J. and S. O'Connor 2017 Traditions and change in scaphopod shell beads in northern Australia from the Pleistocene to the recent past. In D.E. Bar-Yosef Mayer, C. Bonsall and A.M. Choyke (eds), *Not Just for Show: The Archaeology of Beads, Beadwork, and Personal Ornaments*, pp.4–18. Havertown: Oxbow Books.

Balme, J. and S. O'Connor 2019 Bead making in Aboriginal Australia from the deep past to European arrival: Materials, methods, and meanings. *PaleoAnthropology, Special Issue: Personal Ornaments in Early Prehistory* 2019:177–195.

Balme, J., S. O'Connor and M.C. Langley 2018 Marine shell ornaments in northwestern Australian archaeological sites: Different meanings over time and space. In M. Langley, M. Litster, D. Wright and S.K. May (eds), *The Archaeology of Portable Art: Southeast Asian, Pacific, and Australian Perspectives*, pp.258–273. Oxon: Routledge.

Berry, M. 2018 Murujuga Desert, Tide, and Dreaming: Understanding Early Rock Art Production and Lifeways in Northwest Australia. Unpublished PhD thesis, CRAR+M, University of Western Australia. Perth:

Campbell, G. 2017 The reproduction of small prehistoric tusk shell beads. In D.E. Bar-Yosef Mayer, C. Bonsall and A.M. Choyke (eds), *Not Just for Show: The Archaeology of Beads, Beadwork, and Personal Ornaments*, pp.168–180. Havertown: Oxbow Books.

Clement, E. and J.D.E. Schmeltz 1903 *Ethnographical Notes on the Western-Australian Aborigines*. Leyden: E.J. Brill.

d'Errico, F., C. Henshilwood, M. Vanhaeren and K. van Niekerk 2005 *Nassarius kraussianus* shell beads from Blombos Cave: Evidence for Symbolic behaviour in the Middle Stone Age. *Journal of Human Evolution* 48(1): 3–24.

Goldwyer, W.R. 2018 An Archaeological Investigation of Late Holocene Shell Bead Manufacture, Dampier Archipelago, North-Western Australia. Unpublished BA(Hons) thesis, Department of Archaeology, University of Western Australia, Perth.

Konishi, S. and A. Paterson 2021 History by design in the Kimberley. In G. Sculthorpe, M. Nugent, and H. Morphy (eds), *Ancestors, Artefacts, Empire: Indigenous Australia in British and Irish Museums*, pp.121–130. London: The British Museum Press.

Lamprell, K.L. and J.M. Healy 1998 A revision of the Scaphopoda from Australian waters. *Records of the Australian Museum, Supplement* 24:1–189.

Langley, M.C., C. Clarkson and S. Ulm 2019 Symbolic expression in Pleistocene Sahul, Sunda, and Wallacea. *Quaternary Science Reviews* 221:105883.

Larson, P.A. 1978 Ornamental beads of the Late Natufian of southern Israel. *Journal of Field Archaeology* 51:120–121.

Litster, M., D. Wesley and G.M. Stolte 2018 Developing approaches for understanding Indigenous Australian glass bead use during the contact period. In M. Langley, M. Litster, D. Wright and S.K. May (eds), *The Archaeology of Portable Art: Southeast Asian, Pacific, and Australian Perspectives*, pp.299–318. Oxon: Routledge.

Litster, M., A. Barham, J. Meyer, T.R. Maloney, … S. O'Connor 2020 Late Holocene coastal land-use, site formation and site survival: Insights from five middens at Cape Leveque and Lombadina, Dampier Peninsula, Kimberley, Australia. *Australian Archaeology* 86(2): 118–136.

McAdam, L.E.S. 2008 Beads Across Australia: An Ethnographic and Archaeological View of the

Patterning of Aboriginal Ornaments. Unpublished PhD thesis, Armidale: Archaeology and Palaeoanthropology, School of Humanities, University of New England.

McDonald, J., W. Reynen, Z. Blunt, K. Ditchfield, … P. Veth 2023a Chapter 6: Enderby Island excavations. In J. McDonald and K. Mulvaney (eds), *Murujuga: Dynamics of the Dreaming 2014-2018: Rock Art, Stone Structures and Excavations Across the Murujuga Cultural Landscape*, pp.127–214. CRAR+M Monograph 2. Perth: UWA Publishing.

McDonald, J., W. Reynen, K. Ditchfield, Z. Blunt, … P. Veth 2023b Chapter 15: Burrup Peninsula excavations at Watering Cove and Old Geos. In J. McDonald and K. Mulvaney (eds), *Murujuga: Dynamics of the Dreaming 2014-2018: Rock Art, Stone Structures and Excavations Across the Murujuga Cultural Landscape*, pp.591–646. CRAR+M Monograph 2. Perth: UWA Publishing.

McDonald, J., W. Reynen, Z. Blunt, K. Ditchfield, … J. Dortch 2023c Chapter 8: Rosemary Island excavations. In J. McDonald and K. Mulvaney (eds), *Dynamics of the Dreaming 2014-2018: Rock Art, Stone Structures, and Excavations Across the Murujuga Cultural Landscape*, pp.271–340. CRAR+M Monograph 2. Perth: UWA Publishing.

Maloney, T.R., S. O'Connor, I.E. Dilkes-Hall and M.C. Langley 2018 Late Holocene edge-ground axe production and marine shell beads from Brooking Gorge 1 Rockshelter, southern Kimberley. *Australian Archaeology* 84(2):196–202.

Martin, K.R., L.P. Waits and C.E. Parent 2021 Teaching an old shell new tricks: Extracting DNA from current, historical, and ancient mollusk shells. *BioScience* 71(3): 235–248.

Meggitt, M.J. 1962 *Desert People: A Study of the Walbiri Aborigines of Central Australia*. Sydney: Angus & Robertson.

Mellars, P. 2005 The impossible coincidence. A single-species model for the origins of modern human behaviour in Europe. *Evolutionary Anthropology: Issues, News, and Reviews* 14(1):12–27.

Morse, K. 1988 Mandu Mandu Creek Rockshelter: Pleistocene human coastal occupation of North West Cape, Western Australia. *Archaeology in Oceania* 23(3): 81–88.

Morse, K. 1993a Shell beads from Mandu Mandu Creek rock-shelter, Cape Range Peninsula, Western Australia, dated before 30,000 b.p. *Antiquity* 67(257):877–883.

Morse, K. 1993b Who can see the sea? Prehistoric Aboriginal occupation of the Cape Range Peninsula. In W.F. Humphreys (ed.), *The Biogeography of Cape Range, Western Australia*, pp.227–242. Records of the Western Australian Museum 45. Perth: Western Australian Museum.

Peggs, A.J. 1903 Notes on the Aborigines of Roebuck Bay, Western Australia. *Folklore* 14(4):324–367.

Roth, W.E. 1910 Decoration, deformation and clothing. *North Queensland Ethnography Bulletin* 15. Sydney: Records of the Australian Museum.

Schall, A. 1985 *Aboriginal Use of Shell on Cape York. Cultural Resources Monograph Series 6*. Brisbane: Department of Community Services, Queensland Government.

Smith, A.M. and H.G. Spencer 2016 Skeletal mineralogy of scaphopods: An unusual uniformity. *Journal of Molluscan Studies* 82(2):344–348.

Stephenson, B. 2016 Investigation of a Shell Bead, 'WP1 912361 XU2', Wadjuru Pool, Rosemary Island, Western Australia. Unpublished report to Centre for Rock Art Research + Management, University of Western Australia Perth.

Stiner, M.C. 2014 Finding a common bandwidth: Causes of convergence and diversity in Paleolithic beads. *Biological Theory* 9(1):51–64.

Thomson, D.F. 1934 The dugong hunters of Cape York. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland* 64:237–262.

Vanhaeren, M. and F. d'Errico 2001 La parure de l'enfant de la Madeleine (fouilles Peyrony). Un nouveau regard sur l'enfance au Paléolithique supérieur. *Paléo* 13(13): 201–240.

Vermeij, G.J. 1995 *A Natural History of Shells*. Princeton, NJ: Princeton Science Library.

Veth, P., K. Aplin, L. Wallis, T. Manne, … A. Chappell 2007 *The Archaeology of the Montebello Islands: Late Quaternary Foragers on an Arid Coastline. BAR International Series 1668*. Oxford: Archaeopress.

Veth, P., I. Ward, T. Manne, S. Ulm, … P. Kendrick 2017 Early human occupation of a maritime desert, Barrow Island, north-west Australia. *Quaternary Science Reviews* 168:19–29.