

Coastal Occupation before the 'Big Swamp': Results from Excavations at John Wayne Country Rockshelter on Barrow Island

Kane Ditchfield, Tiina Manne, Fiona Hook, Ingrid Ward and Peter Veth

Abstract

In this paper we present a terminal Pleistocene/early Holocene archaeological record from John Wayne Country Rockshelter (JWCR), located on Barrow Island in north-western Australia. The rockshelter was used between 15,000 – 7000 cal. BP and provides insights into how Aboriginal people interacted with a changing coastal landscape throughout post-glacial sea level rise. The faunal record reflects this fluctuating local landscape. The late Pleistocene faunal assemblage largely consists of arid plains terrestrial fauna which transitions to a diverse marine invertebrate taxa midden. This record demonstrates coastal resource use throughout the terminal Pleistocene, before the expansion of mangrove forests across northern Australia. The stone artefact assemblages indicate varied expedient reduction patterns. The assemblages include artefacts manufactured from local limestone and non-local sources. Our analyses indicate that occupation durations at JWCR were longer during the late Pleistocene compared to the early Holocene when productive mangrove environments became proximal. The implications of these results are twofold. First, that effective use of coastal plain environments was likely just as important for coastal occupation as marine resource procurement. Second, that the presence of relatively dense marine faunal assemblages is not necessarily a reliable proxy for individual coastal site occupational intensity under conditions of local resource productivity.

Dans cet article, nous présentons un assemblage archéologique datant du Pléistocène terminal / début de l'Holocène et provenant de l'abri sous-roche 'John Wayne Country Rockshelter' (JWCR), situé sur l'île de Barrow dans le nord-ouest de l'Australie. L'abri a été utilisé entre 15 000 et 7 000 cal. BP et permet d'appréhender la façon dont les anciens Aborigènes ont interagi avec un paysage côtier en constante transformation durant la hausse des niveaux marins de la période postglaciaire. Les assemblages fauniques reflètent ce paysage local fluctuant. L'assemblage archéozoologique du Pléistocène tardif est en grande partie constitué de faune terrestre des plaines arides avant d'être remplacé par un dépôt riche en taxons d'invertébrés marins. Ces assemblages enregistrent une utilisation des ressources côtières durant tout le Pléistocène terminal, avant l'expansion des forêts de mangroves dans le nord de l'Australie. Les assemblages d'outillage lithique indiquent des schémas variés de débitage opportuniste. Les assemblages comprennent des outils fabriqués à partir du calcaire local et de sources non-locales. Nos analyses indiquent que les durées d'occupation à JWCR furent plus longues pendant le Pléistocène tardif qu'au début de l'Holocène, lorsque les milieux productifs de mangrove devenaient plus proches. Les implications de ces résultats sont doubles. Premièrement, l'utilisation efficace des environnements de plaines côtières était probablement tout aussi importante que l'approvisionnement en ressources marines pour l'occupation du littoral. Deuxièmement, la présence d'assemblages relativement denses de faune marine n'est pas nécessairement un

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indicateur fiable de l'intensité d'occupation de sites côtiers individuels dans des conditions où les ressources locales sont productives.

Keywords: coastal archaeology; Pleistocene; early Holocene; north-west Australia, Big Swamp Phase

Mots Clés: archéologie de paysage côtier, Pléistocène, début de l'Holocène, le nord-ouest de l'Australie

Introduction

Palaeoenvironmental and archaeological records across northern Australia register evidence for prominent and widespread mangrove ecosystems in association with transgressing Pleistocene sea levels (e.g. Allen 1996; Clune & Harrison 2009; Grindrod et al. 1999; Harrison 2009; McDonald & Berry 2017; Thom et al. 1975; Woodroffe 1990; Woodroffe et al. 1988). This is sometimes referred to as the 'Big Swamp Phase' (Proske et al. 2014; Woodroffe et al. 1985, 1989) although the extent and timing of this has not been definitively demonstrated across the entire north-west coast (Ward et al. 2015). Such estuarine ecosystems are argued to be important both as economic 'hotspots' for coastal people and in forming 'coastal adaptations' (e.g. Bulbeck 2007; Erlandson & Braje 2015; Marean 2014). This is due to their extremely high productivity and ability to support numerous trophic links between a wide variety of species (Woodroffe 1993, 1999; Woodroffe et al. 1988:101). Indeed, Australian ethnographic records show that Aboriginal people used mangrove and estuarine habitats to provide wood for rafts, fuel and artefacts, as well as to procure a variety of subsistence resources including fruit, fish, mud-worms, crustaceans, crocodiles and bats, in addition to a broad array of molluscan and benthic faunas (Akerman 2015; Faulkner 2013; Meehan 1982). Accordingly, many archaeological sites in northern Australia register significant evidence for mid-Holocene estuarine resource exploitation (e.g. Allen 1996; Clune & Harrison 2009; O'Connor 1996; Przywolnik 2002).

However, most of these archaeological sites only provide chronological evidence for coastal occupation and estuarine resource exploitation from the mid to late Holocene (cf. Manne & Veth 2015; Morse 1993). The problem is that little is known about Aboriginal interaction with, and occupation of, changing terminal Pleistocene coastal landscapes prior to the 'Big Swamp Phase' between 10,000 cal. BP – 5,500 cal. BP (Mulrennan & Woodroffe 1998; Proske et al. 2014; Woodroffe et al. 1985). Indeed, occupation of these coastal landscapes may also include successful use of coastal plain resources in addition to marine resources (*sensu* Erlandson 2001; Hallam 1987). To help address this issue, the archaeological record for a site located on the uplands of Barrow Island, known locally as John Wayne Country Rockshelter (JWCR; Figure 1), is presented in this paper. The JWCR record helps supplement the c. 50,000 cal. BP archaeological record from nearby Boodie Cave (Veth et al. 2014, 2017; Ward et al. 2017) by providing a more contracted archaeological record that documents Aboriginal use and occupation of a changing coastal landscape from 15,000 to 7,000 years ago. By presenting chronological, geoarchaeological, faunal and stone artefact analyses for JWCR, we aim to reconstruct how Aboriginal people interacted with a changing coastal landscape as terminal Pleistocene sea levels transgressed along the North-West Shelf.

<Note: Please place Figure 1 here>

Regional Context: Palaeoenvironmental and Archaeological Background

Terminal Pleistocene

The terminal Pleistocene in north-western Australia is characterised by post-LGM sea level rise, climatic amelioration, and the large-scale re-initiation of the Indo-Australian Summer Monsoon (IASM) by 14,000 cal. BP, which facilitated higher summer rainfall, humidity and resulted in vegetation change (Denniston et al. 2013; Fitzsimmons et al. 2013; Griffiths et al. 2009; Johnson et al. 1999; Reeves et al. 2013; Wyrwoll & Miller 2001). Vegetation and sediment reconstruction from a deep-sea core, Fr10/95, GC17 (Figure 1) shows a pronounced rise in mangroves (*Rhizophoraceae*) from the terminal Pleistocene in conjunction with a rise in local summer rainfall (van der Kaars & De Deckker 2002; van der Kaars et al. 2006). Sediment records from Boodie Cave also document an increasing marine-derived carbonate-dominated assemblage from the terminal Pleistocene (Ward et al. 2017, 2018).

Terminal Pleistocene coastal occupation is registered in nearby Cape Range (Pilgonaman Creek, Yardie Well and Jansz Rockshelters), on the Montebello Islands (Noala Cave) and at Boodie Cave on Barrow Island (Manne & Veth 2015; Morse 1993; Przywolnik 2002; Veth et al. 2007, 2014, 2017). Most of these archaeological assemblages comprise mixed marine-terrestrial fauna (including chiton (*Acanthopleura spinosa*), limpet (*Patella* spp.), baler shell (*Melo* spp.), turtle, macropods, snakes, emu egg shell, fish and crustaceans). Boodie Cave has a rich faunal record from the Pleistocene – Holocene transition, including 40 molluscan and 13 terrestrial species amongst dense lithic assemblages, shell beads and modified shell tools (Veth et al. 2017). Veth et al. (2007:23, 2017) characterise this dietary record as a broad, mixed, arid coastal plains economy where reef, estuarine, rocky platform and sandy bay environments were systematically exploited along with suites of terrestrial prey from the arid, sandy, rocky upland and hummock coastal plain (also see Manne & Veth 2015; Przywolnik 2002; Ward et al. 2013).

Early to mid-Holocene

By the early to mid-Holocene the IASM culminates at 8,000 – 6,000 cal. BP leading to the highest levels of precipitation, humidity and vegetation cover (Denniston et al. 2013; Griffiths et al. 2009; Wyrwoll & Miller 2001). Coastal plains were inundated as Barrow Island and the Montebello Islands began to form, initially as one large super-island (Ward et al. 2013). By c. 7,000 cal. BP, Barrow Island and the Montebello Islands became separated and assumed their current forms (Veth et al. 2007; Ward et al. 2013, 2015). A +2m sea level high-stand occurred locally at 6,800 cal. BP (Collins et al. 1993, 2003; Twiggs & Collins 2010) followed by a slow regression. Although not specifically documented on the North West Shelf (Ward et al. 2015), the 'Big Swamp Phase' is represented in deep-sea records (van der Kaars & De Deckker 2002; van der Kaars et al. 2006) and in northern Cape Range (Wyrwoll et al. 1993), declining dramatically by 6,000 – 5,000 cal. BP.

During this period, there is an exponential increase in excavated archaeological evidence for Aboriginal coastal occupation across the north-west (see Manne & Veth 2015; McDonald &

Berry 2017; Morse 1993; Przywolnik 2002; Veth et al. 2007, 2014, 2017) and, for the first time, numerous surface scatter midden sites (e.g. Morse 1993, 1996; Przywolnik 2002, 2003). Most early to mid-Holocene faunal assemblages from these sites reflect increased shoreline proximity combined with expanded mangrove ecosystems. For example, the faunal assemblages from Boodie, Noala and Haynes Cave become increasingly dominated by diverse marine fauna (including baler shell (*Melo* spp.), oyster (*Saccostrea* spp.), sea urchin (*Echinoidea*), parrot fish (*Scarus* sp.) and turtle (*Cheloniidae*) as the coastline transgresses (Veth 1993; Veth et al. 2007, 2014, 2017; Manne & Veth 2015). The mangrove mudwhelk (*Terebralia palustris*) becomes dominant along with smaller proportions of mud snail (*Cerithidia reidi*) and mud crab (*Scylla serrata*). These assemblages also contain freshwater mussel and a range of terrestrial fauna including small, medium and large marsupials, snakes and monitor lizards. Together the faunal assemblages demonstrate that a diverse range of environments were accessible including sand plains, dune fields, limestone plateaus, rocky shores, fringing reefs, inter-tidal mudflats, mangroves and protected embayments.

John Wayne Country Rockshelter (JWCR): Local Context

JWCR is a west-facing rockshelter perched 34 m above mean sea level in a limestone bluff on Barrow Island's north-west coast (Figure 2). Its position in the bluff affords a panoramic view over a dune system to the narrow coastal plain. The rockshelter is located approximately 100 m from an ephemeral creek system to the south. Based on a combined sea level curve presented in Ward et al. (2015), JWCR would have been located approximately 16 km from the terminal Pleistocene coastline at 12,000 cal. BP and 2 km from the early Holocene coastline at 8,000 cal. BP (Figure 3). The rockshelter is approximately 13m wide, 7.5m deep and up to 1.8m in height (Figure 2) with over 1.5m of deposit. The site was excavated in 2014 as part of the Barrow Island Archaeology Project (Veth et al. 2014, 2017). The sample size recovered from JWCR is smaller than that of Boodie Cave, with only one 1 x 1m sample square (designated as G3) being excavated (see Figure 2). G3 was excavated following the same procedure as Boodie Cave (see Veth et al. 2017) with the exception that all sediments were dry sieved (rather than wet sieved) through nested 4 mm and 2 mm sieves. Specific excavation data alongside detailed archaeological data are presented as Supplementary Material for this paper (Section S1). The assemblages recovered from this excavation are low in density and small in size, certainly by comparison with Boodie Cave. Our analyses and discussions are tempered to acknowledge these limitations. However, small assemblages can still have considerable analytical value and our analyses not only aim to carefully reconstruct the behavioural reasons for such assemblage compositions at JWCR but also to contextualise them within wider landscape patterns.

<Note: Please place Figures 2 and 3 here>

Results

Stratigraphy and Sediments

The stratigraphy for JWCR is summarised in Figure 4. Macroscopically the sediments from Square G3 comprise poorly sorted, light brown (5YR 5/6) coarse sandy sediment, with angular limestone fragments (up to 1 – 2 cm) and minor shell (2%), in addition to degraded bone fragments (< 2%). With increasing depth, sediments grade into darker (5YR 5/8), compacted silty sands, with minor shell (2%) and few or no bone fragments. Micromorphological analysis is presented in the Supplementary Material (Section S2) and indicates the presence of minor shell, degraded bone fragments, disaggregated grass and plant fragments, and plant-based dung in surface sediments. Whilst localised reworking is evident from exposed rootlets, particularly in the north and west walls (Figure 4), there is minimal evidence for significant vertical reworking below the topmost unit.

<Note: Please place Figure 4 here>

Laser particle size analyses of sediments show a predominantly bimodal distribution and a distinct clay shoulder, with the main modal peaks at ~340 μm and 1100 μm , and a relatively constant grain size distribution with depth. Carbonate digestion indicates that the sediments comprise ~ 90% carbonates throughout the profile, much of which is likely locally-derived. The remaining 10% comprises siliciclastic material. These results imply a relatively constant source and/or depositional processes over the accumulation period represented by these sediments.

Chronological Analyses

The radiocarbon data for JWCR is presented in Table 1 where calibrations are in accordance with ShCal13 (Hogg et al. 2013). Marine shell radiocarbon dates were obtained from *Terebralia* sp. samples. They were calibrated using both the Marine13 calibration dataset (Reimer et al. 2013) and the regional ΔR value for the Montebello Islands/Barrow Island area (109 ± 25) reported by Veth et al. (2017). It should be noted that this value was calculated on suspension-feeding bivalves rather than *Terebralia* which may reflect carbon from a variety of sources, but this has yet to be quantified by any researchers in the north-west. *Terebralia* sp. belong to the same superfamily as Cerithidea. Petchey et al.'s (2013) study at Caution Bay in southern Papua New Guinea shows that *Cerithidea* sp. show more variation in ^{14}C than all other shellfish examined as part of their study, with ΔR values ranging between -291 ± 39 to 219 ± 39 ^{14}C years. The radiocarbon dates on *Terebralia* sp. reported here should be interpreted with this larger error in mind.

Optically stimulated luminescence (OSL) determinations are presented in Table 2. The measurement protocols for both radiocarbon (AMS at Waikato Radiocarbon Laboratory) and OSL (Environmental Luminescence & Institute of Photonics and Advanced Sensing, Adelaide) are the same as those reported for Boodie Cave (Veth et al. 2017) and are not repeated here. All OSL results use a central age model except for Ad14037 which, based on

statistical parameters (Arnold et al. 2009), requires the minimum age model. The details for OSL dating are provided in Supplementary Material (Section S3.1).

<Note: Please place Tables 1 and 2 here>

The JWCR chronology is largely in stratigraphic order and shows some level of stratigraphic differentiation providing further evidence that the deposit has good overall stratigraphic integrity. Certainly, there is clear evidence of rootlets and the occasional small burrow, particularly on the North and West walls (Figure 4), so some degree of reworking is assumed for this section. As in Boodie Cave, this reworking largely occurs within sedimentary units (i.e. syn-sedimentary) rather than between them (Ward et al. 2017). However, Wk-40412, which is dated to 9322 ± 56 cal. BP, is stratigraphically associated with Ad14040 which returned a determination of $14,900 \pm 1130$ cal. BP. Even at Ad14040's full error range ($13,770 - 16,030$ cal. BP) there is no overlap between these dates. Wk-40412 falls out of stratigraphic order when considered against the age determinations above it (Figure 4) which may indicate localised reworking. However, Wk-40412 is the only sample which was not collected *in situ* (i.e. it is a sieve sample; Table 1). As a result, we argue that it is likely to be a post-excavation intrusion (e.g. it represents contamination by charcoal from younger layers) and thus was rejected.

Using OxCal 4.2, Bayesian analysis was undertaken on the remainder of the dates (see Bronk Ramsey 2009). The methodological details for the Bayesian analysis are provided in the Supplementary Material (Section S3.2). The analyses returned robust results (Table S5; Figure S3). All OSL and radiocarbon age determinations have agreement indices of over 95 while the model itself has an $A_{overall}$ value of 107.6. All age determinations have less than a 10% chance of being outliers while the convergence values are also high. The model suggests that the JWCR deposit began accumulating at $17,418 \pm 3591$ cal. BP. SU5 continued to accumulate until $14,553 \pm 1586$ cal. BP before transitioning to SU4 at $13,489 \pm 892$ cal. BP. SU4 continued to accumulate over 939 ± 1133 years until $11,646 \pm 839$ cal. BP and transitioned to SU3 at $10,783 \pm 888$. SU3 spans 1281 ± 408 years until 8496 ± 1458 cal. BP before abandonment in SU2 at 7329 ± 1797 cal. BP. This age of abandonment accords well with other sites across the larger North West Shelf (Veth et al. 2014).

Based on the stratigraphy and Bayesian model, it is possible to identify two broad archaeological analytical units. The first analytical unit, SU3, is an early Holocene midden unit and includes all excavation units (XUs) from 6 – 21. Drawing on data from the Supplementary Material (Section S1), XU21 was selected as the last unit for SU3 since it reaches a depth 60 cm (the approximate boundary of SU3, see Figure 4). Because both SU4 and SU5 have similar transitional chronologies (both being terminal Pleistocene and lying between $15,000 - 12,000$ cal. BP), and to increase sample size, these units were combined into SU4/5. This analytical unit includes XUs 22 – 30. A third, non-archaeological, analytical unit is SU1/2 which includes XUs 1 – 5 that accumulated following rockshelter abandonment.

Vertebrate Faunal Assemblages

Vertebrate fauna were identified using comparative skeletal reference material held at the University of Queensland Archaeology Fauna Laboratory and the Terrestrial Vertebrate

Collections of the Western Australian Museum. Teeth, cranial and post-cranial specimens were assigned to either their lowest taxonomic level or body size. The maximum length of each specimen was recorded, along with its weight. Using an Olympus LG-PS2 stereomicroscope, each specimen was also examined for percussion and cutmarks, along with other predator damage such as gastric etching or carnivore marks. Recorded taphonomic information included burning (Stiner et al. 1995), bone fracture patterns, secondary calcium carbonate encrustations, root etching, weathering (Behrensmeyer 1978) and manganese staining.

The vertebrate faunal assemblage consisted of 395 specimens, of which 131 could be assigned a taxonomic class (Table 3). A further 135 were assigned a taxonomic body size, leaving 129 specimens designated as non-identifiable. Body-size categories are arbitrary but informed by the types of identified taxa from Boodie Cave along with fauna from Noala and Haynes Caves on the Montebellos (Manne and Veth 2015). The microfauna represents taxa with body weights less than 0.25 kg (such as muridae); small bodied taxa are considered to be those between 0.25–~3 kg (such as *Isoodon auratus barrowensis*, *Trichosurus vulpecula* and *Macrotis lagotis*); medium animals are those between ~3–10 kg, (such as *Lagorchestes conspicillatus* and *Onychogalea unguifera*); and large-bodied taxa are those with weights over > 10 kg (such as *Osphranter robustus isabellinus*).

<Note: Please place Table 3 here>

The dominance of smaller-bodied taxa, along with the fragmented-nature of the assemblage is clearly visible in Figure 5, with most specimens falling between 0.1 and 3.0 cm in length. A large proportion of the remains (52%) were encrusted with calcium carbonate, impeding taphonomic analyses. No cut or percussion marks were noted and only four specimens were burnt, with one specimen designated as carbonised (category 2) and three as calcined (category 5). Five specimens were noted as having pitting, likely from gastric etching and two specimens contained drag marks from a small carnivore. The paucity of small lizard remains, in addition to the relatively good preservation of microfauna, suggests that microfauna were accumulated by a nocturnal owl (Andrews 1990, Baird 1991, Laudet et al. 2002).

<Note: Please place Figure 5 here>

With respect to the representation of taxa, SU4/5 contains a single specimen of bilby (*Macrotis lagotis*), very small quantities of golden bandicoot (*Isoodon auratus*) and mala (*Lagorchestes hirsutus*), along with single specimens from a large and very large bodied macropod. These, along with the three kinds of lizards from this SU (two of which are of economic size), are in concert with what would be expected from a more interior site. Arid, terrestrial taxa still dominate the vertebrate fauna in SU3. The two specimens of unidentifiable fish are small vertebrae and as such, cannot be distinguished between marine or freshwater.

Marine Invertebrate faunal assemblages

The number of identified specimens (NISP), the Minimum Number of Individuals (MNI; Table 4) and shell weight per lowest identified taxon in the 4 mm sieve fraction were used to

characterise marine invertebrate abundance. It should be noted that the MNI calculations are low because of the highly fragmented nature of the assemblage. A combination of NISP and MNI are therefore used in the following discussion. Because of fragmentation most of the sample is identified to genus level. Number of taxa was also calculated to determine species richness and fragmentation rates were used to determine the degree of shell breakage (Section S4; Table S6). We did not use the Simpsons Diversity Index in this study due to the small sample size (cf. Grayson 1984:167; Claassen 1998:119). All shell fragments, at their lowest taxonomic level, were weighed, non-replicable elements identified and all fragments counted. MNI was not calculated for echinoderms and crustaceans due to a lack of reference material.

<Note: Please place Table 4 here>

The identified invertebrate faunal assemblage from square G3 consists of 6119 specimens (an MNI of 332), which weigh a total of 2457.97 grams. As shown in Table 4, most taxa (by NISP, MNI and weight) occur in SU3, between XU 6 and XU21. All specimens identified, apart from *Rhagada* spp. (land snail), are economic having served either as a food resource or for the making of implements or both. *Rhagada* spp. is interpreted as non-economic owing to its steady presence in all three stratigraphic units and the high proportion of whole shells when compared to the other specimens.

SU3 is dominated by *Terebralia* spp. (dog whelk) but also contains the greatest overall number of taxa (9), with *Cerithium nodulosum* (nodulose coral creeper) *Nerita balteata* (periwinkle), *Saccostrea* spp. (oyster) and *Turbo* spp. (turbo) represented along with Muricidae (creeper), crustaceans and echinoderms. *Terebralia* spp. (dog whelk), *Cerithium* spp. (creeper) and *Nerita balteata* (periwinkle) are associated with mangrove systems. *Sacosstrea* spp. (oyster), *Turbo* spp. and Muricidae (creepers) are associated with either rocky shorelines or coral reefs, although *Sacosstrea* spp. (oyster) is also found in mangrove habitats. *Nassarius* spp. (dog whelk) is a near-shore dweller, associated with muddy intertidal flats, while *Brechites* spp. (watering pot shell), although a bivalve, has a thick tubular shell with a small cap (Wilson 2013). It is found on sand flats with rubble beneath the sand, to which the animal can attach itself. Overall, the marine invertebrates are predominantly from mangroves and, to a lesser extent, rocky substrates.

In SU4/5, *Melo* spp. (baler), and *Terebralia* spp. (dog whelk) are found in small quantities, when JWCR was located further inland. The occurrence of *Melo* spp. (baler) in SU4/5 is perhaps unsurprising, considering its well documented utilitarian use such as water carriage and the manufacture of shell knives (Akerman 1973, 1975; Przywolnik 2003). The *Melo* spp. (baler) fragments are generally small suggesting that they are fragments removed during the shaping process of utilitarian objects and are similar to those found in Boodie Cave. Current experimental archaeological studies are underway by Hook and colleagues, to determine the characteristics of both water carrier and shell knife manufacture along with the resultant manufacture debris. Given the presence of associated stone artefacts and economic terrestrial fauna, the presence of *Melo* spp. and *Terebralia* spp. in SU4/5 is argued to be the result of human subsistence and/or manufacturing. This unit has the lowest number of taxa and is dominated by these two genera when the shelter was away from the coast. These species would have been transported 16 km to the shelter (Figure 3). In this

unit there is one specimen of *Tellinella virgate* (tellin). These bivalves are usually located in either slightly muddy near-shore sand flats or, as deep-burrowers, in the mid to lower littoral sand flats (Wilson 2013). Given that that at this time the coast was approximately 16 km away (Figure 3), this specimen was likely transported to the rockshelter as a desirable food species. Supporting evidence comes from *Tellinella* spp dominated shell scatters on the Onslow Coast where the Thalanyji people have specifically stated *Tellinella* spp. were a desirable prey species (F. Hook pers. comm.).

There are small quantities of *Terebralia* spp. and other marine shellfish in SU1/2. These are argued to be the result of post-depositional disturbance following site abandonment and islandisation. Supporting this interpretation is the lack of lithics in SU1/2. In addition, the stratigraphic boundary between SU2 and SU1 is gradational rather than sharp, implying a certain level of reworking across these boundaries. Further evidence of bioturbation is presented in the micromorphology (Supplementary Information S2) with the presence of herbivore excrement in the uppermost unit which is not replicated in the SU4/5 to SU3 boundary. A similar situation exists in Boodie Cave, where the uppermost sediments also have evidence of herbivore excrement and poor pedogenic development (Ward et al. 2017).

The degree of fragmentation of the dominant taxa is high, contrasting with the non-economic species *Rhagada* spp. (land snail) which shows the lowest degree of fragmentation (Section S4; Table S6). In contrast nearby Boodie Cave assemblages (which are still under analysis) has lower *Terebralia* spp. fragmentation rates (459) in Square A103 compared with 235 in SU3 at JWCR.

Stone Artefact assemblage

The stone artefact assemblage at JWCR is small, consisting of 55 artefacts (Table 5). Local limestone is the dominant raw material but three non-local artefacts were recorded. The first is a broken igneous scraper found on the surface and is excluded from the following analyses as it likely in reworked context. The second artefact is an igneous fragment that occurs in the early Holocene midden unit (SU3) while the third is a complete chalcedony flake in the terminal Pleistocene unit (SU4/5). The only major geological formations on the island are limestone-based: the Trealla Limestone, Giralia Calcarenite and 'siliceous limestone unit' (Hickman and Strong 2003). JWCR is located within Trealla Limestone from which large limestone cobbles were acquired for use at the rockshelter (Ditchfield et al. in prep). These occur immediately around the rockshelter. The non-local source locations are currently unknown but the closest known terrestrial igneous or chalcedony source locations are located on the present-day mainland, at least 50 km distant (Veth et al. 2017).

<Note: Please place Table 5 here>

To better characterise and understand assemblage variability, a range of analytical techniques were carefully selected with the small assemblage size in mind. The Geometric Index of Unifacial Reduction (GIUR) and the Proportion of Retouched Edge Index (PRE) were used to measure tool retouch/use intensity (see Hiscock and Clarkson 2005; Kuhn 1990; Law 2009). The cortex ratio was used to assess the expected proportion of cortex in the assemblage (see Dibble et al. 2005; Ditchfield 2016; Douglass et al. 2008). To measure reduction intensity the flake to core ratio, the non-cortical to cortical flake ratio, a flake

diminution test and the scar density index (SDI) were used (see Braun 2006; Holdaway et al. 2004). Artefact classes are defined following Holdaway and Stern (2004). Each of these techniques should reflect the nature of assemblage formation at JWCR regardless of assemblage size. The only possible exception is the cortex ratio which is traditionally applied to larger assemblages to measure artefact transport (Lin et al. 2010). In this case, the cortex ratio is not used to measure artefact transport but only to provisionally establish whether enough cortex remains in the assemblage to account for presence or absence of *in situ* reduction.

The GIUR and PRE results suggest that limestone tool retouch/use intensity was greater during the terminal Pleistocene (SU4/5) in comparison to the early Holocene (SU3; Table 6). The data also show that scrapers are more common in the terminal Pleistocene, while in the early Holocene only one utilised tool and one notched tool occur.

<Note: Please place Table 6 here>

It is only possible to apply the cortex ratio to the terminal Pleistocene units (SU4/5) since it is the only assemblage with cores (see Dibble et al. 2005). The cortex ratio for the terminal Pleistocene assemblage is 1.31. The flake to core and non-cortical to cortical flake ratio results are shown in Table 7. Given the highest proportion of non-cortical flakes occurs in SU4/5, it is likely that terminal Pleistocene core reduction was higher than in the early Holocene. Results for the flake diminution test (Table 8) indicate that terminal Pleistocene flake sizes increase with cortex category, as expected for *in situ* reduction. However, the early Holocene diminution results show the opposite pattern, suggesting reduction did not occur *in situ* from cortical cobbles at this time. It is also worth noting that the early Holocene cortical flakes are very small compared to the terminal Pleistocene specimens.

<Note: Please place Tables 7 and 8 here>

The SDI results are given in Table 9 and generally show that the rockshelter assemblages were minimally reduced. However, the single early Holocene tool returns an SDI value which is much higher than any other artefact from the entire sequence. Most other values show inter-strata similarity while the terminal Pleistocene tools have very low SDI values.

<Note: Please place Table 9 here>

Discussion of Occupational Patterns

Stone Artefact assemblage formation

The stone artefact assemblages demonstrate that occupation at JWCR was episodic and of relatively short duration during both the early Holocene and terminal Pleistocene. These assemblages are small, reflecting expedient reduction and minimal discard. Indeed, together, the stone artefact analyses suggest that cores were never intensively reduced at JWCR. This is an important proxy for occupation duration because core reduction is a time dependent process (Shott and Sillitoe 2005). The longer an occupation, the more intensively cores tend to be reduced *in situ* (Shott 2010), leading to more flakes per core and less cortical assemblages. At JWCR, the non-cortical to cortical flake ratios show that the assemblages are disproportionately cortical while the flake to core ratio, where applicable,

shows that very few flakes occur per core. Furthermore, few dorsal scars occur on cores or flakes per unit surface area. On a regional scale, the Noala and Haynes Cave sites on the nearby Montebello Islands have similar assemblages to JWCR, being characterised by their small size and the domination of local materials (Veth et al. 2007). Further analyses are required but it is likely that terminal Pleistocene – early Holocene occupation at Noala and Haynes Cave was also short-lived. In contrast, the terminal Pleistocene assemblages in nearby Boodie Cave are dense, displaying a wider variety of lithologies (Veth et al. 2017). This partly reflects a lower average sedimentation rate in Boodie Cave (4 cm/ka) compared to John Wayne rockshelter (6.5 cm/ka) over the same time period but, regardless, the Boodie Cave assemblage compositions reflect much longer and/or more frequent occupations.

Although we believe short occupations exerted the most significant influence on stone artefact assemblage formation at JWCR, there are some important changes in assemblage composition that hint at behavioural change over time. For example, some indices suggest that terminal Pleistocene occupations were longer than in the early Holocene. The cortex ratio shows that enough cortex remains in the terminal Pleistocene assemblage to account for *in situ* cortical core reduction. This suggests that occupations were long enough for Aboriginal people to procure immediately available limestone nodules and minimally reduce these *in situ* rather than relying on their transported tool-kit (*sensu* Kuhn 2004). It is important to distinguish longer occupations from more frequent occupations here. If the larger terminal Pleistocene assemblage was the result of more frequent occupations with similar durations to the early Holocene we could expect less use of local nodules and a greater reliance on the transported tool-kits since there will be less time to procure local nodules for expedient reduction and use in place of the transported tool-kit (e.g. Kuhn 2004). The terminal Pleistocene assemblage composition does not suggest this to be the case.

Minimal terminal Pleistocene *in situ* reduction is also demonstrated by the flake diminution results showing that flake size increases with cortex category. This is an important result because large cortical flakes are usually the first flakes removed from nodules during reduction and such flakes should be present if cortical nodules were knapped *in situ*. The GIUR and PRE results suggest that terminal Pleistocene tools were the most heavily retouched and used at JWCR, also indicating longer terminal Pleistocene occupation, as longer occupations provide more opportunity to use tools *in situ*, probably to conserve transported tool-kits (which likely consisted of non-local materials as attested by the chalcedony flake). The terminal Pleistocene tools are large (166.0 cm²), all cortical and have low SDIs (Table 9) showing that Aboriginal people selected the largest flakes, from the earliest stages of core reduction, for use at the rockshelter.

The same is clearly not the case for the early Holocene since only a small sample of flake debris remains in the assemblage with no large cortical flakes (see Table 8). Unlike the terminal Pleistocene, this pattern suggests occupation events were not long enough for Aboriginal groups to create cortical assemblages from local cortical nodules; instead they may have relied on transported tool-kits. However, there is only one complete early Holocene tool. It is relatively small (33.0 cm²), has no cortex and its GIUR and PRE values are consistent with minimal use. These statistics suggest it was knapped from an intensively

reduced core (intensive reduction tends to produce smaller flakes with less cortex). This interpretation is supported by the high tool SDI value which indicates numerous artefacts were knapped from the parent core before this tool was produced. The pattern suggests that the early Holocene tools were produced from transported cores for expedient *in situ* use during short occupations at JWCR. Independent evidence for shorter early Holocene occupations at JWCR comes from the low JWCR shell fragmentation rate when compared with Boodie Cave under the assumption that longer occupation creates more fragmented shell assemblages via processes such as trampling.

Faunal Assemblages

The terrestrial and marine faunal assemblages show similar shifts during the Pleistocene-Holocene transition as recorded at Boodie, Noala and Haynes Caves (Manne and Veth 2015; Veth et al. 2007, 2017). These sites demonstrate a shift from predominantly arid plains fauna to one that incorporates estuarine and marine taxa. In particular, the continuing and increasing presence of *Terebralia* spp. in these sites, as at JWCR, indicates that mangrove stands were present during both the late Pleistocene and early Holocene before their decline towards the minimal distributions witnessed today.

The dominant shellfish during the late Pleistocene, *Melo* spp., likely relates to utilitarian, rather than dietary purposes (e.g. shell knife manufacture or water carriage; Akerman 1973). The two terminal Pleistocene dietary taxa are *Tellina* spp. and *Terebralia* spp. and these may indicate that Aboriginal people were exploiting mangrove, estuarine and sand-flat environments along the terminal Pleistocene coastline. It is important to emphasise that the relative scarcity of economic shellfish is not likely to represent an unproductive coast (*sensu* O'Connell & Allen 2012) but rather the distance JWCR is from the coast at this time (over 16 km). Indeed, the presence of *Terebralia* spp. and *Tellina* spp., which are almost certainly dietary, probably indicates a productive coast despite sea level transgression. Clearly, Aboriginal people were occupying and using the coastal plain as well as the inter-tidal zone along the shoreline.

Increased early Holocene mollusc diversity and abundance reflects the proximity of the inter-tidal zone resulting from sea level transgression. As the coastline neared, Aboriginal people could more easily transport a variety of shell species to JWCR for consumption. This is not to say that it was a preferred location for marine food consumption or that Aboriginal people were not able to easily access marine subsistence resources before this time, but that it was simply easier to do so at JWCR during the early Holocene. Indeed, since occupation duration at JWCR was shortest during the early Holocene, it is likely that coastal Aboriginal people spent most of their time elsewhere (e.g. immediately processing and consuming shellfish adjacent to shorelines as indicated by regional midden sites; Morse 1993, 1996; Przywolnik 2002).

Despite challenges in interpreting small sample sizes, it is worth comparing the JWCR terminal Pleistocene terrestrial faunal record against the nearby sites of Boodie, Noala and Haynes Cave (Manne and Veth 2015; Veth et al. 2017). All these assemblages reveal similar patterns of economic prey including *O. robustus*, *L. conspicillatus*, *L. hirsutus*, *T. vulpecula*, *M. lagotis* and *I. auratus* along with large elapids and medium-sized skinks and varanids. Although owls may have contributed to the remains of *I. auratus* at JWCR, the lack of this

species in SU1/2, tentatively suggests that people consumed *I. auratus*. Like Noala, Haynes and Boodie Cave, we note the presence of large and medium-sized macropods during both the Pleistocene and early Holocene. A single tooth from *M. lagotis* in SU4/5 is also in keeping with patterns observed at Noala and Boodie Cave. Finally, the presence of a calcaneus from a very large macropod in SU 4/5 is intriguing. It is heavily encrusted with calcium carbonate and currently cannot be refined taxonomically, however additional work is being undertaken which may further resolve this identification.

Implications and Conclusions

There are several implications arising from the JWCR analyses. Perhaps the most important is that the JWCR record provides insights into the use of coastal landscapes prior to the 'Big Swamp' phase. On a regional scale the terminal Pleistocene and early Holocene were climatically favourable periods with warm temperatures and relatively high precipitation brought about by the IASM's southward extension at this time. Occupation across the region was clearly diverse and dynamic. This is clearly shown by the stark contrast between JWCR's - and, indeed, Noala and Haynes Cave's - archaeological records and that of Boodie Cave. While much work still remains to be done on the Boodie Cave assemblages, the site was likely occupied persistently and sometimes for long periods given its assemblage density while the other sites display only episodic occupation. Despite favourable climatic conditions, not all locales on a diverse landscape were used equally. Indeed, nor was this the case through this time at JWCR. Occupations were always episodic there, although the archaeological record does suggest that it was occupied for longer periods during the terminal Pleistocene, when it was part of the coastal plain (being approximately 16 km from the shoreline). This pattern is especially interesting as we might expect the proximity of productive mangrove stands to encourage longer occupations at JWCR during the early Holocene. Instead the opposite seems to be true. JWCR appears to have been more 'attractive' for occupation when part of a coastal plain than when adjacent to the coastline. Not only does such a pattern suggest that marine productivity is not necessarily a good indicator for occupational intensity or duration, but also that an effective use of interior coastal plain environments was just as important to coastal adaptive systems as marine food procurement (see also Erlandson 2001; Hallam 1987). This observation may be easily overlooked when dietary marine food resources are (not unsurprisingly) privileged as indicators of a successful coastal adaptation (e.g. Marean 2014). Nearby Boodie Cave provides further support for this proposition with a dense terminal Pleistocene mixed marine and terrestrial faunal assemblage (Veth et al. 2017). In combination, these records indicate that both marine *and* adjacent arid coastal plain landscapes were economically integrated prior to sea level stabilisation. Indeed, the presence of *Tellina* spp., *Terebralia* spp. and *Melo* spp. from the terminal Pleistocene deposits at JWCR, along with the 40+ molluscan species identified at Boodie Cave (from the Pleistocene – Holocene transition) hint at the integration of productive marine zones in combination with the terrestrial fauna on the semi-arid coastal plains.

Another important implication is that JWCR provides independent (now off-shore) evidence from the Pilbara and Carnarvon coastal region for the exploitation of coastal resources by Aboriginal people from the terminal Pleistocene. Mangrove resources were available and transported 10+ kilometres inland, although they do become especially important during

the 'Big Swamp' phase of the early Holocene. These patterns accord well with nearby islands sites (e.g. Veth et al. 2007, 2017), sites on the Cape Range coast (e.g. Morse 1993; Kendrick and Morse 1996) and from the Pilbara maritime provinces (e.g. McDonald and Berry 2017; Clune & Harrison 2009). Aboriginal people repeatedly exploited apparently productive coastal ecosystems, discarding mangrove shellfish and crustaceans in near-shore locations, including elevated rockshelters like JWCR. Indeed, Boodie Cave also includes a terminal Pleistocene – early Holocene anthracological record (Veth et al. 2017) which demonstrates exploitation of white mangroves (*Avicennia marina*) and ribbed mangroves (*Bruguiera exaristata*) from nearby shorelines. At JWCR marine molluscs and crustaceans from mangrove habitats were most intensively discarded during SU3 which has a chronology of 10783 ± 888 to 8496 ± 1458 cal. BP. This age range is markedly earlier than many sites on Cape Range (Morse 1993; Veth et al. 2014) and the Dampier Archipelago (McDonald and Berry 2017). At the regional level this demonstrates that Aboriginal people exploited productive mangrove ecosystems as sea levels rose towards Barrow Island and beyond. These data do not support notions that rapid sea level rise, including melt-water pulse events, significantly diminished marine productivity during the terminal Pleistocene. When combined with earlier coastal assemblages from the region (e.g. Morse 1993; Przywolniak 2002; Veth et al. 2017), we conclude that the JWCR record represents a continuation of a much older coastal economy which integrated marine resources from Pleistocene coastlines with those from the arid coastal plains on the now drowned North West Shelf.

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Table List

Table 1 Radiocarbon determinations for square G3 at John Wayne Country Rockshelter. 'XU' stands for Excavation Unit, 'SU' for Stratigraphic Unit and 'Col' for Collection Method. Depth is given in cm and weight is given in grams. In the Material ('Mat') column, 'C' stands for charcoal and 'MS' for marine shell.

Lab ID	XU	SU	Depth	Col.	Mat.	Species	BP	cal. BP	D ¹⁴ C	F ¹⁴ C
Wk-40408	6	3	19.7	<i>In-situ</i>	MS	<i>Terebralia</i> ¹	8776 ± 26	9341 ± 52	-664.6 ± 1.1	33.5 ± 0.1
Wk-40409	8	3	28.7	<i>In-situ</i>	MS	<i>Terebralia</i> ²	8697 ± 25	9239 ± 67	-661.3 ± 1	33.9 ± 0.1
Wk-40410	18	3	45	<i>In-situ</i>	C	N/A	9114 ± 31	10,229 ± 26	-678.4 ± 1.3	32.2 ± 0.1
Wk-40411	26	4	97.1	<i>In-situ</i>	C	N/A	11,237 ± 40	13,063 ± 45	-753.1 ± 1.2	24.7 ± 0.1
Wk-40412	28	5	109.3	4mm	MS	<i>Terebralia</i> ³	8758 ± 27	9322 ± 56	-663.9 ± 1.1	33.6 ± 0.1

¹ δ¹³C = -6.47 ± 0.3

² δ¹³C = -5.44 ± 0.2

³ δ¹³C = -6.1 ± 0.3

Table 2 The OSL determinations for square G3 at John Wayne Country Rockshelter. 'SU' stands for Stratigraphic Unit while dose rate is given in mGy⁻¹.

Lab code	SU	Depth	Grains (n)	De (Gy)	Sd (%)	U (ppm)	Th (ppm)	K (%)	Dose rate	Age (ka)
Ad14037	2	30	33	2.3 ± 0.2	44	6.4 ± 3	12.5 ± 0.9	32 ± 3	0.53 ± 0.05	2.5 ± 0.5
Ad14038	3	60	88	5.7 ± 0.2	23	5.8 ± 1.7	13.4 ± 0.9	35 ± 3	0.54 ± 0.04	10.6 ± 0.8
Ad14039	4	80	88	7.3 ± 0.2	24	7.8 ± 2.6	14.1 ± 0.9	38 ± 2.6	0.6 ± 0.05	12.1 ± 1
Ad14040	5	100	126	9.9 ± 0.2	22	8.7 ± 2.2	15.5 ± 1	52 ± 3	0.66 ± 0.05	14.9 ± 1.1

Table 3. Vertebrate specimen counts and weights (grams) for each major stratigraphic unit, consisting of specimens assigned to taxonomic class or body-size, along with non-identifiable bone.

Specimen	SU1/2		SU3		SU4/5	
	N	Weight	N	Weight	N	Weight
Muridae	1	0.04	28	3.54	24	1.98
<i>Isoodon auratus</i>	-	-	14	0.98	6	0.66
Peramelidae	-	-	1	0.15	4	1.09
<i>Macrotis lagotis</i>	-	-	-	-	1	0.16
<i>Trichosurus vulpecula</i>	-	-	1	0.21	-	-
<i>Lagorchestes hirsutus</i>	-	-	-	-	5	1.04
<i>Lagorchestes conspicillatus</i>	-	-	6	6.52	-	-
<i>Osphranter robustus</i>	-	-	5	17.52	-	-
Small macropod	-	-	1	0.08	-	-
Medium macropod	4	2.32	6	5.04	-	-
Large macropod	1	0.69	7	5.85	1	0.18
Very large macropod	-	-	-	-	1	30.74
Aves (medium size)	-	-	-	-	1	1.3
Scincidae (medium size)	-	-	-	-	1	0.03
Varanidae (medium size)	-	-	2	0.18	2	0.46

Agamidae (small size)	-	-	-	-	1	0.22
Elapidae (large size)	-	-	5	0.89	-	-
Fish	-	-	2	0.38	-	-
Microfauna	1	0.02	26	1.68	26	1.65
Small-bodied	8	0.58	13	1.47	26	3.15
Medium-bodied	-	-	11	7.68	13	5.73
Large-bodied	-	-	10	9.86	1	0.32
Non-identifiable bone	2	1.37	78	6.76	49	2.87
Total	17	5.02	216	68.79	162	51.58

Table 4. Marine invertebrate specimen number of identifiable specimens (NISP), minimum number of individuals and weight (grams) and number of taxa for each major stratigraphic unit, consisting of specimens assigned to Genus for Mollusca and Class for Echinodermata and Malacostraca.

Specimen	SU1/2			SU3			SU4/5		
	NISP	MNI	Weight	NISP	MNI	Weight	NISP	MNI	Weight
Brechites	2	1	6.19	-	-	-	-	-	-
Cerithium	-	-	-	3	2	37.2	-	-	-
Mancinella	-	-	-	2	2	42.62	-	-	-
Melo	-	-	-	15	-	6.17	11	-	64.6
Nassarius	1	1	-	-	-	-	-	-	-
Nerita	-	-	-	16	4	6.17	-	-	-
Rhagada*	56	11	8.42	846	103	131.88	582	95	105.05
Saccostrea	-	-	-	6	1	14.45	-	-	-
Tellinella	-	-	-	-	-	-	1	1	6.66
Terebralia	111	3	38.29	4193	99	1781.2	9	2	137.8
Turbo	1	1	0.01	31	6	19.65	-	-	-
Echinoidea	27	-	8.32	161	-	32.4	1	-	3.22
Malacostraca	-	-	-	44	-	7.72	-	-	-
Total	198	17	61.23	5317	217	2079.4	604	98	317.33
NTAXA		5			9			4	

* non economic species

Table 5 Count of flake classes, corrected and uncorrected for volume, organised by stratigraphic unit at John Wayne Country Rockshelter. 'n/m³' stands for number of artefacts per cubic metre.

Flake Class	SU3		SU4/5		Total
	n	n/m ³	n	n/m ³	
Angular Fragment	5	7.9	1	3.7	6
Broken Flake	4	6.3	1	3.7	5
Broken Tool	0	0.0	0	0.0	1
Complete Flake	5	7.9	11	40.7	16
Complete Split	4	6.3	4	14.8	8
Complete Split Tool	1	1.6	1	3.7	2
Complete Tool	1	1.6	2	7.4	3
Core	0	0.0	2	7.4	2
Distal Flake	6	9.5	3	11.1	9
Distal Split	1	1.6	1	3.7	2
Proximal Flake	1	1.6	0	0.0	1
Total	28	44.4	26	96.3	55

Table 6 The results of retouch index analyses for limestone complete, broken and core tools, as well as different tool types.

Type	SU3			SU4/5		
	n	GIUR	PRE	n	GIUR	PRE

Complete Tools	1	0.177	0.130	2	0.592	0.222
Complete and Broken Tools	1 - 2	0.32	0.130	2 - 3	0.563	0.222
Core Tool	0	-	-	1	-	0.167
Notch	1	0.463	-	0	-	-
Scraper	0	-	-	3	0.563	0.203
Utilised	1	0.177	0.13	0	-	-

Table 7 The flake to core and non-cortical to cortical flake ratios.

Flake to Core Ratio	MNF	C	F:C
SU3 Limestone	9.5	0	-
SU4 Limestone	15.5	2	7.75
Non-Cortical to Cortical Flake Ratio	NCF	CF	NCF:CF
SU3 Limestone	1	5	0.2
SU4 Limestone	5	8	0.625

Table 8 A flake diminution test for complete flakes. Size is given as surface area (cm²).

Material	0%		1-50%		51-100%	
	n	μ	N	μ	n	μ
SU3 Limestone	1	32.98	2	18.78	3	17.21
SU4 Limestone	5	16.99	3	76.06	5	108.70

Table 9 The results for the SDI applied to limestone complete flakes and tools along with cores.

Limestone Artefacts	Number	SDI
SU3 Complete Flakes	5	0.72
SU3 Complete Tools	1	1.99
SU4 Complete Flakes	11	0.92
SU4 Complete Tools	2	0.31
SU4 Core	1	0.72
SU4 Core Tool	1	1.16

Figure Caption List

Figure 1. Regional map showing the location of major archaeological sites mentioned in-text along with bathymetric contours.

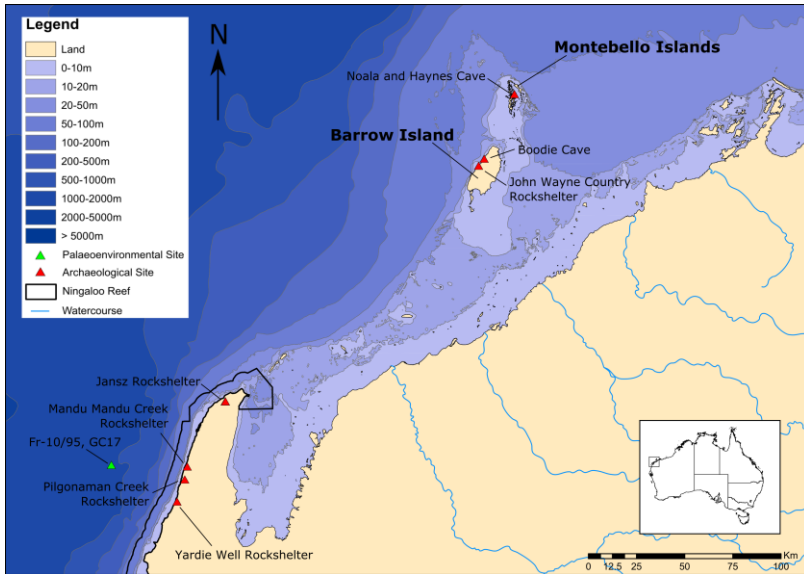


Figure 2. Composite figure showing the exterior of, and site plan for, JWCR. CS1 shows the rockshelter dripline while CS2 shows part of the rockshelter interior.

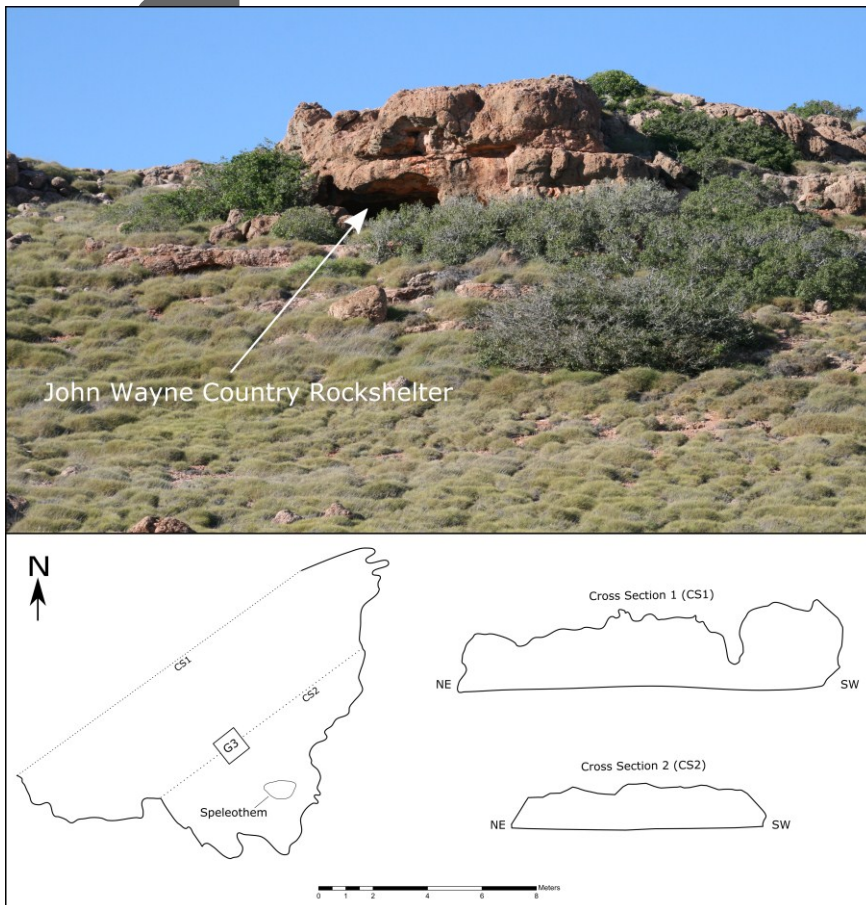


Figure 3. Cross section off the western coast of the Barrow Island through JWCR with approximate sea levels (Ward et al. 2015). Cross section runs directly west.

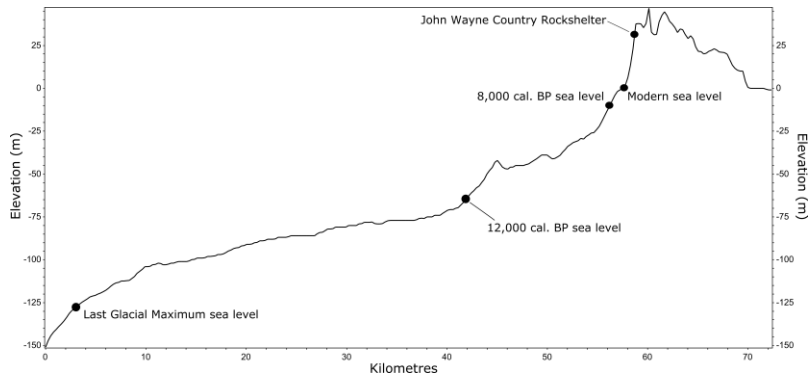


Figure 4. Section drawing of JWCR, showing five conformable stratigraphic units distinguished mainly by colour and composition. Position of OSL samples and sediment monolith in the South wall are shown in photo (left), with final chronology presented on the section drawing (right).

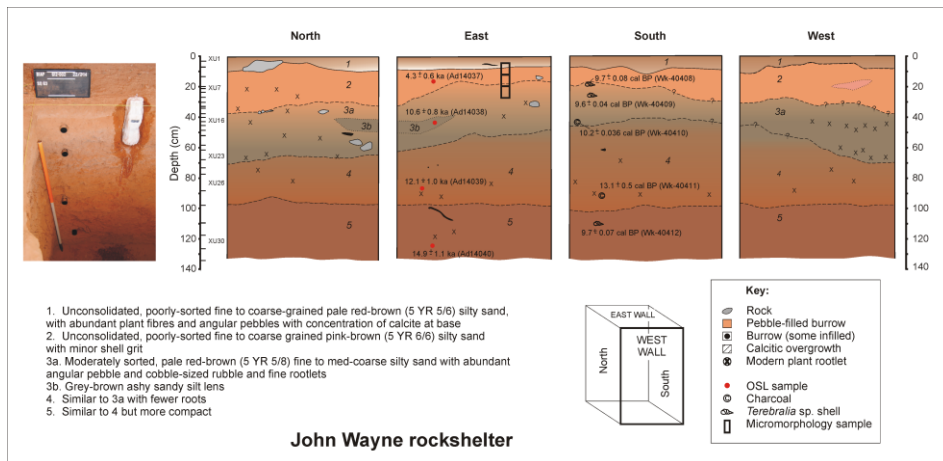


Figure 5. Specimen fragment length size classes, with 0.1mm to 2cm size specimens dominating all three stratigraphic units.

