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## The curious case of Proteaceae: macrobotanical investigations at Mount Behn rockshelter, Bunuba country, Western Australia

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### ABSTRACT

Macrobotanical analyses, which offer important information about human-environment interactions of the past, are underdeveloped in Australia due to limited reference materials, poor preservation of organic remains and inadequate field sampling strategies. Wood, seeds, fibres and resin provide invaluable information on diet, technology and human-environment interaction. When excavated from stratified archaeological deposits, macrobotanical remains enable analysis at a scale that is spatio-temporally linked with human occupation, unlike broad-scale palaeo-environmental records, which defy correlation with short-time human responses. Analyses of wood charcoal and seeds were identified and analysed from Mount Behn rockshelter, Bunuba country, in the southern Kimberley region of Western Australia, where the largest stone point assemblage for the region was excavated. Neither the anthracological nor carpological records reflect the taxon richness of vegetation communities of the modern vegetation, precluding both palaeo-environmental reconstruction and in-depth exploration of resource management and use. Certain taxa are over-represented in the anthracological and carpological records, in particular, Proteaceae wood charcoal and *Celtis* spp. endocarps, and we explore how anthracological and carpological spectra are artefacts of preservation, with particular reference to other macrobotanical research that has been conducted in the Kimberley region and Western Australia.

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Australian archaeology; anthracology; carpology; vitrification; hunter-gatherer; resource management; taphonomy

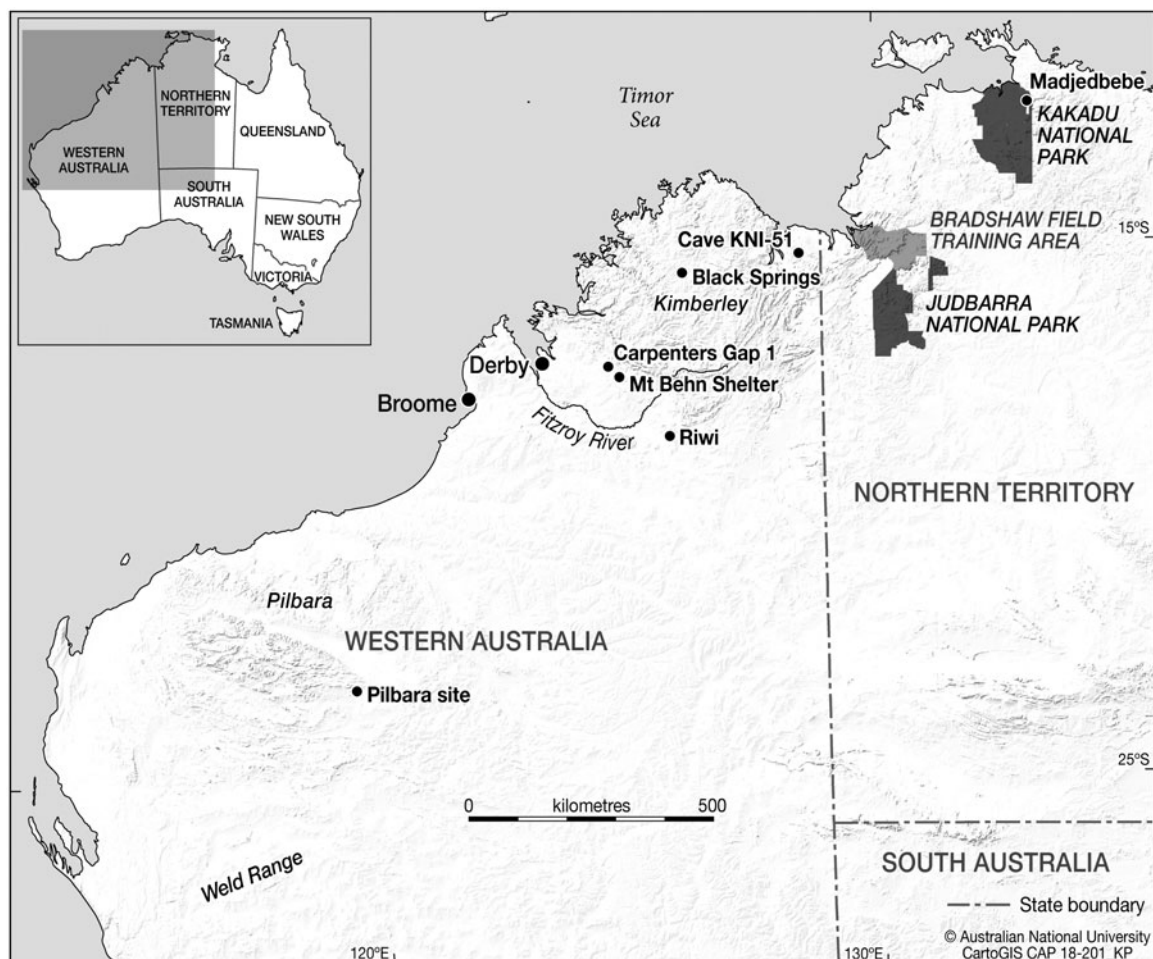
### Introduction

Mount Behn rockshelter yielded the largest assemblage of the retouched stone artefacts known as points excavated from the Kimberley region to date (Maloney et al. 2017). Applying technological criteria and morphological analyses to the Mount Behn unifacial and bifacial point assemblages, Maloney et al. (2017) present the first substantial demonstration of a point reduction continuum in the Kimberley, akin to those observed in the Northern Territory and Queensland (Clarkson 2002, 2007; Hiscock 1994, 2006). Maloney et al. (2017) argue that the majority of points were discarded during the deposition of SU3 and SU4, between 3,815–3,575 cal. BP (ANU-33031) and 1,835–1,710 cal. BP (ANU-46907), a period which they associate with an El Niño-Southern Oscillation (ENSO) phase of aridity and inferred foraging risk, between approximately 2,400 and 1,200 cal. BP (Conroy et al. 2008; Denniston et al. 2013; Donders et al. 2007, 2008; Field et al. 2017; Gagan et al. 2004; McGowan et al. 2012; Moy et al. 2002; Rein et al. 2005; Rodbell et al. 1999; Schulmeister 1999). This view aligns with other reduction based analyses of

stone tool assemblages in Northern Australia, which have linked changes in stone tool reduction strategies with adaptation to increases in aridity and inferred foraging risk (Clarkson 2002, 2007; Hiscock 1994, 2006; Hiscock and Attenbrow 2002; Hiscock and Veth 1991; Maloney et al. 2014; Maloney and O'Connor 2014; O'Connor et al. 2014).

The lack of detailed palaeoenvironmental data available from the area does not allow for a precise correlation of human-environment interaction. For example, the 2,400 and 1,200 cal. BP arid phase is based on palaeoclimate records located at some distance from Mount Behn rockshelter, with the closest palaeoenvironmental archive, Black Springs, some 230 km northeast of the site and offering a local, rather than regional vegetation reconstruction (Figure 1; Field et al. 2017; McGowan et al. 2012). The obvious solution to this issue is to reconstruct the local vegetation from the archaeobotanical remains recovered from Mount Behn rockshelter and explore human-environment interaction throughout the site's occupation.

Of the suite of botanical fossils that can be obtained from archaeological contexts,



**Figure 1.** Western Australia with sites mentioned in the text and inset of Australia, including Black Springs (Field et al. 2017); Cave KNI-51 (Denniston et al. 2013); Carpenters Gap 1 (Frawley 2009); Madjedbebe (Carah 2016); and Riwi (Whitau et al. 2016a). Note that precise coordinates cannot be provided for the Pilbara (Dotte-Sarout and Byrne 2013) and Weld Range (Byrne et al. 2013) sites due to confidentiality agreements (figure produced by CartoGIS, Australian National University).

macrobotanical remains offer the most unambiguous signature of human manipulation. Wood, seeds, fibres and resin provide invaluable information on diet, technology and human-environment interaction. When excavated from stratified archaeological deposits, macrobotanical remains enable analysis at a scale that is spatio-temporally linked with human occupation, unlike broad-scale palaeo-environmental records, which defy correlation with short-time human responses (Holdaway et al. 2010). However, macrobotanical remains are organic and perishable and so their survival depends on an array of taphonomic factors. The most common mode of preservation is through carbonisation via charring, whether direct (e.g. wood for fuel), or indirect (e.g. seeds in the sediment are burned, or waste is thrown on a fire). Depending on the context, the anaerobic conditions provided by waterlogged or desiccated sediments are more or less likely to offer the opportunity for organic remains to preserve, or certain types of macrobotanical remains might mineralize through the absorption of certain compounds from certain types of sediments (Pearsall 2015).

In Australia, analyses of macrobotanical remains have enabled exploration of resource use and

management, landscape use, diet and mobility patterns, in the tropical regions of the Northern Territory and Queensland (Carah 2016; Clarke 1989; Cosgrove et al. 2007, Ferrier and Cosgrove 2012); the tropical Kimberley (Atchison 2009; Atchison et al. 2005; Dilkes-Hall 2014; McConnell and O'Connor 1997; Whitau et al. 2016a, 2016b), and semi-arid New South Wales (Fullagar et al. 2008). However, these studies are rare, as macrobotanical research remains under-developed in Australia. Indeed, since Denham et al.'s (2009) summary of archaeobotanical work conducted in Sahul, only a handful of macrobotanical studies have been conducted on the Australian continent, including five published works (Byrne et al. 2013; Dotte-Sarout et al. 2015; Ferrier and Cosgrove 2012; Whitau et al. 2016a, 2017), and three unpublished theses (Carah 2016; Dilkes-Hall 2014; Florin 2014).

Some Australian archaeological contexts do not allow botanic remains to be well preserved (cf. Denham et al. 2009; Dotte-Sarout et al. 2015); for example, the alternate wetting and drying of the monsoonal north does not favour the production of anaerobic environments, and the complex

sedimentation processes observed within rockshelters, the most commonly excavated context in Australia (Williams et al. 2014), limit the creation of suitable deposits. Poor preservation is not the limiting factor of macrobotanical research; wood charcoal is one of the most ubiquitous archaeological remains, and yet its potential as an indicator for human-environment interaction is only beginning to be explored in Australia (cf. Dotte-Sarout et al. 2015). Inadequate field sampling strategies and the lack of reference materials continue to hinder the application of archaeobotanical techniques.

The purpose of this paper is to test Maloney et al. (2017)'s foraging risk hypothesis, by exploring human-environment interaction at Mount Behn rockshelter throughout its occupation sequence, and comparing local-scale vegetation reconstruction at the site with broader palaeoenvironmental and palaeoclimatic records. Wood charcoal and carpological assemblages are chosen specifically for this purpose, the first because wood charcoal is an appropriate proxy for vegetation reconstruction (Asouti and Austin 2005; Dotte-Sarout et al. 2015), the latter because other macrobotanical remains reveal the best direct evidence for human manipulation of plant resources (Pearsall 2015). Like all archaeological remains, macrobotanic assemblages are artefacts of preservation, and so the taphonomy and representativeness of each assemblage need to be considered for vegetation reconstructions and assessments of human-environment interaction to be valid. An essential aim of this paper, then, is to explore the taphonomy and representativeness of two archaeobotanical assemblages recovered from Mount Behn rockshelter (wood charcoal and seeds/fruits). This aim is particularly important for Australian archaeology, where poor preservation of botanical remains is often cited, but is not necessarily the limiting factor for the application of archaeobotanical analyses, when appropriate recovery techniques, such as flotation, are not regularly applied in the field, and archaeobotanists are often not engaged in the field-work process (Denham et al. 2009).

### Study site

Mount Behn rockshelter is an outcrop of the central Napier Range within the traditional lands of the Aboriginal Bunuba people, in the southern Kimberley region of Northern Western Australia, located some 100 km from the current coastline (Figure 1). Situated within the tropical zone, the rockshelter receives an average of 700 mm of rainfall per annum, most of which falls within the wet season (October–May) of the Australian summer monsoon (Bureau of Meteorology 2015). The rockshelter, which is formed at the intersection of Behn conglomerates and Napier limestone (Playford et al. 2009), sits some 10 m above a plain at the top of a 15° talus slope (Figure 2). Approximately 40 m in length, between 2 and 10 m in depth and 2 m in height with a deep overhang, the rockshelter's ceiling and walls are almost entirely covered in rock art, which is both stylistically diverse and profusely superimposed. Soot also extensively covers the lower part of the ceiling. The surface of the shelter is littered with lithic artefacts including grinding stones, and a collection of lithic artefacts is also housed in a bower bird nest at the front of the cave.

A white fig (*Ficus virens*) grows within the shelter, while various trees and shrubs, including boab (*Adansonia gregorii*), *Vitex* sp., *Celtis strychnoides*, waterbush (*Myoporum montanum*), and white currant (*Flueggea virosa*) grow underneath the overhang, obscuring the view to the shelter from below (Figure 2). The limestone outcrop supports a sparse steppe of spinifex (*Triodia bitextura*), with boabs and other low trees such as kurrajong (*Brachychiton viscidulus*), kapok bush (*Cochlospermum fraseri*) and bloodwoods (*Corymbia* sp.). This steppe grades into greybox/cabbage gum (*Eucalyptus tectifical/Corymbia grandifolia*) savanna woodland with high ribbon grass (annual *Sorghum* sp.) and subsidiary *Corymbia cadophora*, *Hakea arborescens*, *Grevillea* sp. and *Acacia* sp. across the plain below. An ephemeral creek adjacent to the rockshelter supports riparian vegetation dominated by paperbarks (*Melaleuca* sp.) and sedges.



Figure 2. Mount Behn rockshelter outcrop (photographs and photograph montage by Dorcas Vannieuwenhuysse).

## Methods

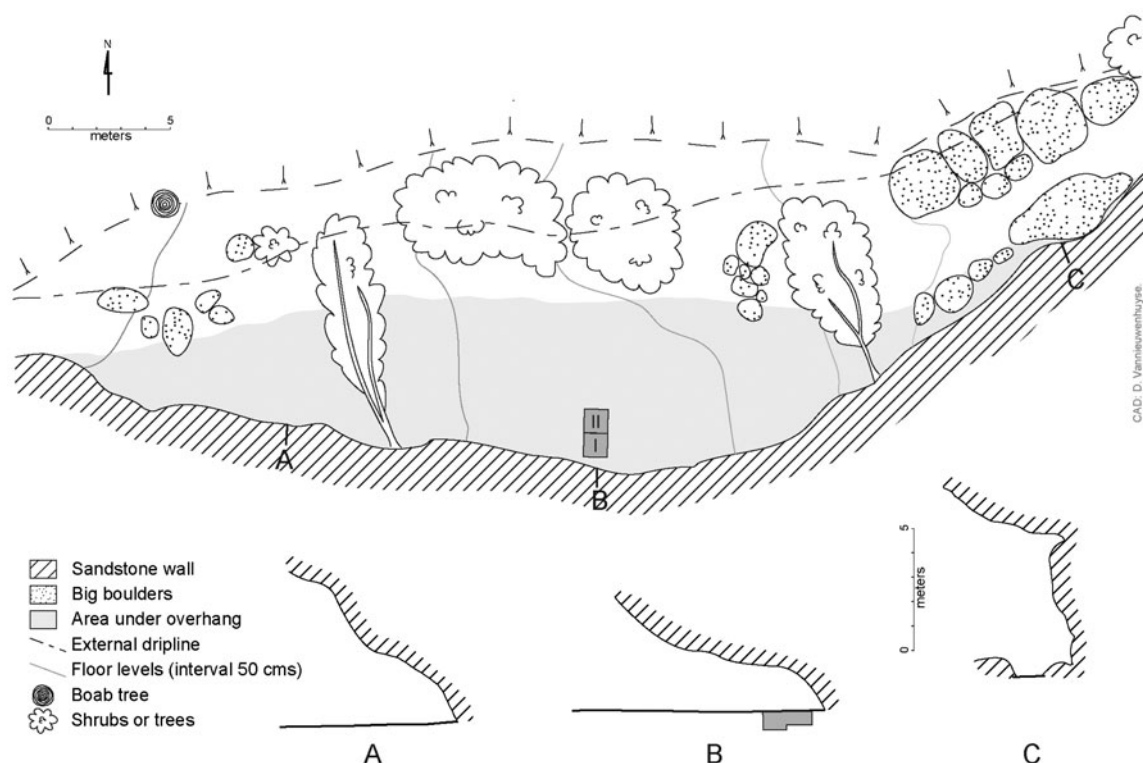
### Site chronostratigraphic sequence and excavation methods

In 2012, a 2 × 1 m trench (Squares 1 and 2) was excavated near the central back wall of Mount Behn rockshelter (Figures 3 and 4; Maloney et al. 2017; Vannieuwenhuysse 2016). While Square 1 was excavated to bedrock at a depth of 70 cm, Square 2 was excavated until sterile deposits were reached at a depth of 50 cm. Seven stratigraphic units (SU) were identified in the field (Figure 4). The upper part of the sequence, SU5 to SU1, from c.40 to 50 cm below to the surface of the deposit and dated to the late Holocene, are archaeologically rich with recovered material including lithic artefacts, animal bone fragments, plant remains, charcoal, freshwater shell, scaphopod beads and fragments of painted wall. The boundary between the sterile lower deposit and the archaeologically rich deposits of the upper sequence are clear in some parts of the exposed stratigraphy and diffuse in others. SU5, for example, was created by the mixing of SU6 and SU4. Boundaries within the upper part of the sequence were also diffuse and difficult to differentiate. SU2 is a discontinuous rocky layer that only appears in the northern and western sections of the trench. The main occupation layers are SU4, SU3 and SU1. Several flat combustion features interpreted as hearths are interspersed throughout SU4–SU1.

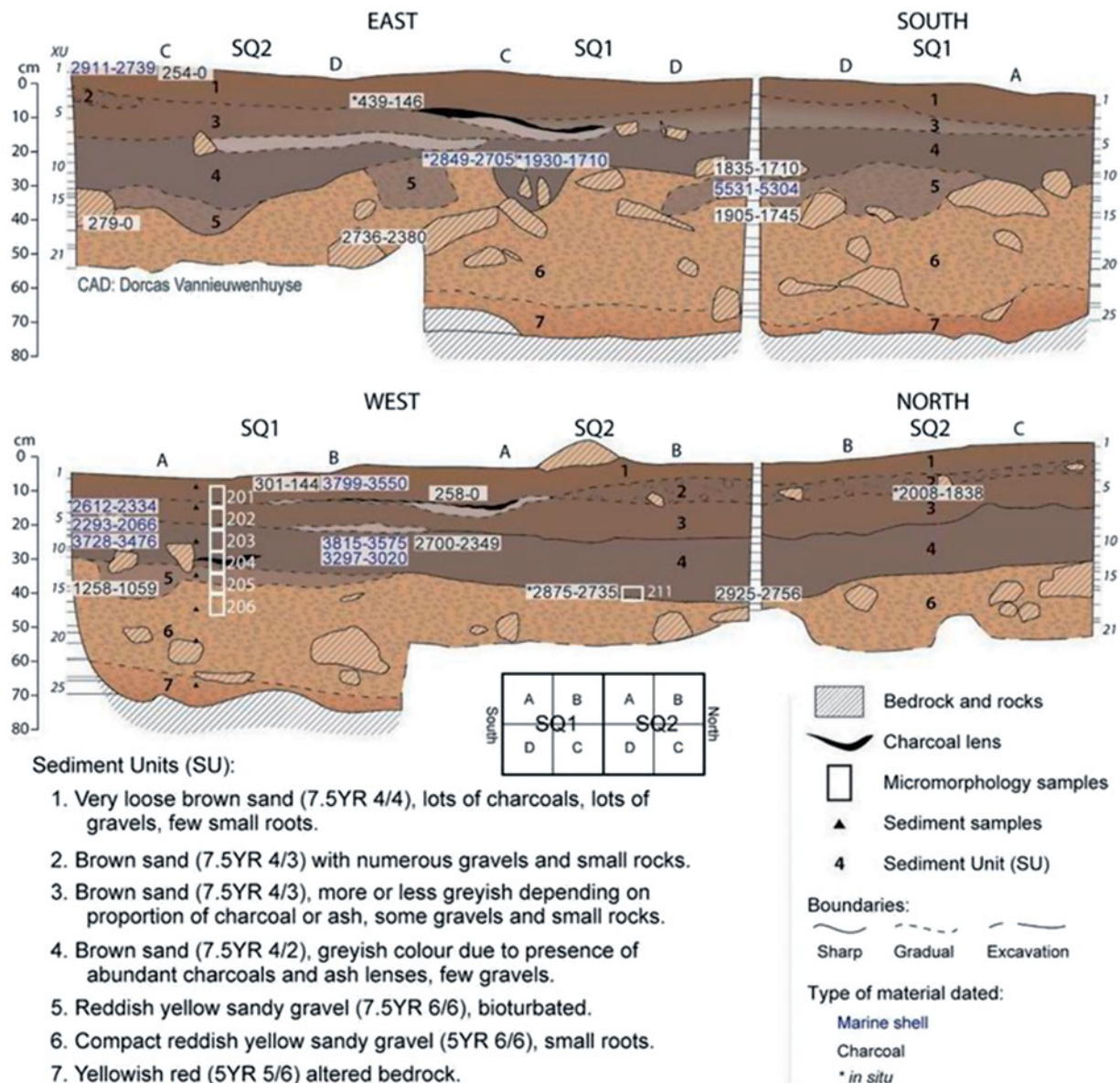
Radiocarbon ages were obtained from seed, charcoal and the marine shell of which scaphopod beads

are composed (Maloney et al. 2017; Vannieuwenhuysse 2016). Based solely on the charcoal chronology, the SU4 and SU3 age is bracketed between 3,815–3,575 cal. BP (ANU-33031) and 1,835–1,710 cal. BP (ANU-46907) and SU1 between 439–146 cal. BP and recent times (ANU-32631, ANU-46909). The marine shell ages are older than those of the charcoal, with the oldest radiocarbon age of 5,531–5,304 cal. BP (ANU-33033) determined from a bead recovered from SU5. Beads from the SU1 deposit were directly dated to 3,799–3,550 cal (ANU-33107) and 2,739–2,211 cal. BP (ANU-32510) (Balme and O'Connor 2017). The disparities between the marine and charcoal chronologies are most likely a combination of post-depositional perturbation of deposit and spatio-temporal distances between the acquisition of the scaphopod material, its varying cultural consumption (as discussed in Balme and O'Connor 2017), and burial at Mount Behn rockshelter, which is over 100 km from the current coastline (Figure 1).

Each square was excavated in 2 cm vertical spits × 50 cm horizontal quadrants. The deposit was dry-sieved through nested 5 and 1.5 mm mesh screens, except for a sediment sample of 2–3 L from Square 2 Quadrant C, within each vertical excavation unit (XU), which was bucket-floated, the heavy residue of which was wet sieved, on site. A bulk sediment sample was collected from each vertical XU in both squares for laboratory analyses. Flat hearths, which had laterally diffuse boundaries, are more obvious in section than they were during excavation and were



**Figure 3.** Mount Behn shelter plan showing the location of the excavation squares and shelter sections from western, central and eastern areas (topographic survey and CAD by Dorcas Vannieuwenhuysse).



**Figure 4.** Mount Behn Squares 1 and 2 stratigraphic sections with descriptions of each SU and the location of micromorphological and sediment samples. (CAD by Dorcas Vannieuwenhuysse).

not removed separately. No off-site pits were dug due to time constraints.

### Laboratory methods

#### Anthracological methods

By assessing the stratigraphic profile (Figure 4), XU depths and excavation notes, charcoals could be sampled from each of the stratigraphic contexts, and any XU that were stratigraphically mixed were avoided (Table 1). All of the charcoal fragments greater than 2 mm<sup>2</sup> were analysed from SU5–1, including both the flot and heavy residue from the floated sample. Charcoals were identified by snapping fragments along the transverse, radial and tangential longitudinal sections, with the aid of a scalpel where necessary (Leney and Casteel 1975). Exposed sections were examined with an Olympus BH-2 reflected lightfield/darkfield microscope

(Japan) at magnifications of 20–500×, with rare or type examples selected for observation and imaging with a JEOL JCM-6000 Neoscope Scanning Electron Microscope (SEM) (Japan). Quantification was conducted by count, rather than weight, following Chabal (1990, 1992) and Théry-Parisot et al. (2010).

The Bunuba-Gooniyandi reference collection (ANU), which was created for this project, and includes Riwi cave, a Pleistocene archaeological site located within Gooniyandi people's lands (Figure 1; Balme 2000), consists of 84 taxa collected over two successive field seasons (July 2013, April 2014); and two wood samples from the Australian National Botanical Gardens (Whitau et al. 2016a). Following Pearsall (2015), wood samples were wrapped in aluminium foil and charred at 400°C in a muffle furnace until smoke was no longer produced. This reference collection was further supplemented by an additional 12 charcoal samples from the University

**Table 1.** Stratigraphic units (SU) and Excavation Units (XU) from which anthracological and carpological materials were collected, XU that were sampled for flotation are in bold.

SU	Description	XU			Material	Radiocarbon age (BP)	Calibrated age (95.4% probability range, cal BP)
		Square I	Square II	Lab.code			
1	Very loose brown sand (7.5YR 4/4), lots of charcoals, lots of gravels, few small roots	–	2B, 2C	ANU 46912	Charcoal	108 ± 26	254–0
				ANU 46909	Charcoal	224 ± 25	301–144
				ANU 32631	Charcoal	265 ± 35	439–146
2	Brown sand (7.4YR 4/3) with numerous gravels and small rocks	–	4B				
3	Brown sand (7.5YR 4/3), more or less greyish depending on proportion of charcoal or ash, some gravels and small rocks	2A, 2C	5C, 6B, 6C, 7B	ANU 32509	Seed	2,020 ± 34	2,008–1,838
4	Brown sand (7.5YR 4/2), greyish colour due to abundant charcoals and ash lenses, few gravels	6D, 7A, 7D, 8A, 8D, 9A,	11A, 11B, 11C, 12A, 12B, 12C, 13A, 13B	ANU 32507	<i>Celtis</i> seed	1,955 ± 30	1,930–1,747
				ANU 46907	Charcoal	1,884 ± 26	1,835–1,710
				ANU 32513	Charcoal	2,460 ± 35	2,700–2,349
				ANU 32632	Charcoal	2,775 ± 35	2,925–2,756
				ANU 32512	Charcoal	2,715 ± 45	2,875–2,734

Associated radiocarbon dates are calibrated against SHCal13 (Hogg et al. 2013) in OxCal v.4.2 (Bronk Ramsey 2009) following the radiocarbon chronology presented in Maloney et al. (2017) and Vannieuwenhuysse (2016).

of Western Australia's Weld Range and Barrow Island reference material (Byrne et al. 2013; Dotte-Sarout and Byrne 2013; Taylor 2012). All reference materials were examined with an Olympus BH-2 reflected lightfield/darkfield microscope (Japan) at magnifications of 20–500×, and imaged with a JEOL JCM-6000 Neoscope Scanning Electron Microscope (SEM) (Japan). The microscopic anatomy of each reference specimen was described following the IAWA list of features, and entered into a database following Dotte-Sarout's (2010) template. Wood identification keys including Hope (1998), Ilic (1991) and two online databases: Inside Wood <<http://insidewood.lib.ncsu.edu/>> and the University of Queensland Online Archaeology Collections <<http://uqarchaeologyreference.metadata.net/archaeobotany/list>> were also employed to aid identification. Where type-level identification could not be positively assigned to a charcoal fragment, it was described as indeterminate. All charcoal fragments that could not be positively identified due to brittleness, vitrification or because they were otherwise too degraded, were assigned indeterminate status with a brief description of why identification was not possible. Vitrified wood has a refringent, glass-like appearance that is produced by the fusion and homogenisation of the anatomical structures of the charcoal (McParland et al. 2010).

### Carpological methods

All carpological remains were analysed from all recovered contexts (5 and 1.5 mm sieves, flot, heavy residue from flotation). Carpological materials from the Mount Behn excavation were hand sorted in the University of Western Australia laboratory under a 10× magnification lamp. Categories based on macroscopic morphological characteristics were

employed and each specimen was described following guidelines provided by the University of Queensland's key criteria,<sup>1</sup> which include shape, surface texture and dimension. The reference collection used to identify carpological material was built from field collections (Dilkes-Hall 2014), previously collected specimens (McConnell 1998) and duplicate vouchered botanical material (Crawford 1982; Smith and Kalotas 1985) housed at the Western Australian Museum. Carpological materials were grouped into burnt/unburnt, and whole/fragmented categories and quantification was conducted by counting the number of individual specimens (NISP).

## Results

### Anthracological results

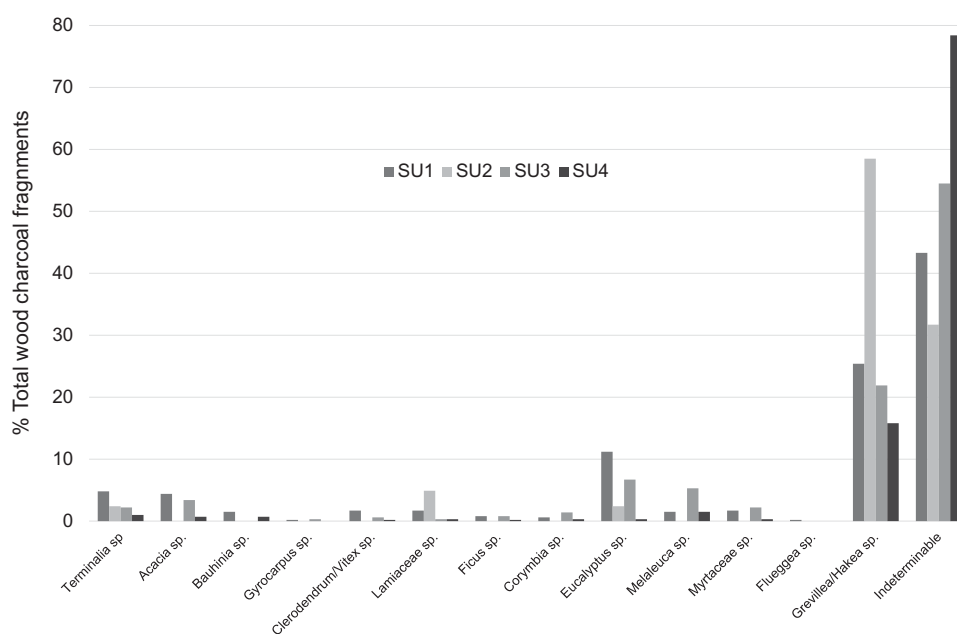
Across the four SUs sampled, a total of 1,513 charcoal fragments were analysed. Of these, 614 fragments were positively identified to varying levels of taxonomic significance. Appendix 1 presents anatomical descriptions of each taxon. A total of 17 taxa, including four unknown types and two family level identifications (Lamiaceae sp. and Myrtaceae sp.), were assigned from eight family groups. Table 2 and Figure 5 show the positively identified taxa, with their relative frequencies for each SU, expressed in terms of absolute fragment counts and proportion of total fragments. Table 3 lists taxa in three broad identification groups (indeterminable, *Grevillea/Hakea* sp., and all other taxa) in relation to their preservation status, in terms of both number and percentage of total fragments for each SU.

The SU1 assemblage has the highest taxon richness (14 taxa), followed by SU3 and SU4 (both with

<sup>1</sup><<http://uqarchaeologyreference.metadata.net/archaeobotany/contribute>>

**Table 2.** Wood charcoal taxa by SU in number of fragments (*n*) and percentage of total fragments (%)

IDENTIFICATION		SU1		SU2		SU3		SU4	
FAMILY	TAXON	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
COMBRETACEAE	<i>Terminalia</i> sp.	25	4.8	1	2.4	8	2.2	6	1.0
FABACEAE	<i>Acacia</i> sp.	23	4.4	0	0	12	3.4	4	0.7
	<i>Bauhinia</i> sp.	8	1.5	0	0	0	0.0	4	0.7
HERNANDIACEAE	<i>Gyrocarpus</i> sp.	1	0.2	0	0	1	0.3	0	0
LAMIACEAE	<i>Clerodendrum/Vitex</i> sp.	9	1.7	0	0	2	0.6	1	0.2
	Lamiaceae sp.	9	1.7	2	4.9	1	0.3	2	0.3
MORACEAE	<i>Ficus</i> sp.	4	0.8	0	0	3	0.8	1	0.2
MYRTACEAE	<i>Corymbia</i> sp.	3	0.6	0	0	5	1.4	2	0.3
	<i>Eucalyptus</i> sp.	58	11.2	1	2.4	24	6.7	2	0.3
	<i>Melaleuca</i> sp.	8	1.5	0	0	19	5.3	9	1.5
	Myrtaceae sp.	9	1.7	0	0	8	2.2	2	0.3
PHYLLANTHACEAE	<i>Flueggea</i> sp.	1	0.2	0	0	0	0.0	0	0
PROTEACEAE	<i>Grevillea/Hakea</i> sp.	132	25.4	24	58.5	78	21.9	94	15.8
UNKNOWN	Type 2	3	0.6	0	0	1	0.3	0	0
	Type 8	1	0.2	0	0	0	0.0	0	0
	Type 14	1	0.2	0	0	0	0.0	0	0
	Type 15	0	0	0	0	0	0.0	2	0.3
INDETERMINABLE		225	43.3	13	31.7	194	54.5	467	78.4
TOTAL		520	100.0	41	100.0	356	100.0	596	100.0


**Figure 5.** Wood charcoal taxa by SU.

10 taxa), while SU2 has the lowest taxon richness, with only four taxa represented (Table 2, Figure 5). SU2 has the lowest proportion of indeterminate charcoals (31.7%), followed by SU1 (43.3%), SU3 (54.5%) and SU4 (78.4%). SU2 and SU4 have the highest proportions of vitrified charcoals (87.8% and 88.9%, respectively), while SU1 has the lowest (61.5%) (Table 3). *Grevillea/Hakea* sp., a type which includes two indistinguishable Proteaceae genera (cf. Whitau et al. 2016b:540) that are considered paraphyletic (Weston and Barker 2006), is the dominant charcoal type across all SU. *Eucalyptus* sp. is the second most dominant taxon after *Grevillea/Hakea* sp. in the SU1 and SU3 assemblages (11.2% and 6.7%, respectively), which are broadly similar units with subsidiary *Acacia* sp., *Melaleuca* sp., and *Terminalia* sp. SU2 is an anomalous unit, comprised

of only 41 charcoals, 24 of which were *Grevillea/Hakea* sp., with two fragments of Lamiaceae sp., and one fragment each of *Terminalia* sp. and *Eucalyptus* sp. SU4, the oldest unit, with the highest proportion of indeterminate charcoals (78.4%), has low proportions of non *Grevillea/Hakea* sp. woody taxa, with only *Melaleuca* sp. and *Terminalia* sp. represented by counts of larger than five fragments (Table 2).

### Carpological results

All of the carpological remains recovered were seeds and fruits, so in the following discussion, we replace the term ‘carpological remains’ with ‘seeds and fruits’. A total of 203 seeds and fruits, which includes dry sieved and floated light and heavy



**Table 3.** Preservation of wood charcoal fragments by SU given in both number of fragments (*n*) and percentage for total assemblage (%) across three groups: indeterminable, *Grevillea/Hakea* sp., and all other taxa.

IDENTIFICATION	PRESERVATION	SU1		SU2		SU3		SU4	
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
INDETERMINABLE	Vitrified	186	82.7	13	100.0	166	85.6	424	90.8
	Vitrified with radial cracks	12	5.3	0	0	16	8.2	16	3.4
	Root/knot wood	6	2.7	0	0	3	1.5	5	1.1
	Brittle	21	9.3	0	0	9	4.6	22	4.7
	TOTAL	225	100.0	13	100.0	194	100.0	467	100.0
GREVILLEA/HAKEA SP.	Vitrified	65	49.2	2	8.3	31	39.7	37	39.4
	Vitrified with radial cracks	52	39.4	21	87.5	38	48.7	53	56.4
	Non-vitrified	15	11.4	1	4.2	8	10.3	4	4.3
	Non-vitrified with radial cracks	0	0.0	0	0.0	1	1.3	0	0.0
	TOTAL	132	100.0	24	100.0	78	100.0	94	100.0
ALL OTHER TAXA	Partly vitrified	5	3.1	0	0	5	6.0	0	0
	Non-vitrified	155	95.1	4	100.0	76	90.5	35	100.0
	Non-vitrified with radial cracks	3	1.8	0	0	3	3.6	0	0
	TOTAL	163	100.0	4	100.0	84	100.0	35	100.0
TOTAL NON-VITRIFIED		200	38.5	5	12.2	100	28.1	66	11.1
TOTAL VITRIFIED		320	61.5	36	87.8	256	71.9	530	88.9

**Table 4.** Seeds per SU for each recovery type: SQ I and SQ II dry-sieved materials, and SQ II flot.

FAMILY	TAXON	SU1	SU2	SU3	SU4
SQI					
ULMACEAE	<i>Celtis</i> spp.	0	0	2	4
TOTAL		0	0	2	4
SQII					
MELIACEAE	<i>Melia azedarach</i>	0	1	0	0
MORACEAE	<i>Ficus</i> sp.	0	0	0	1
ULMACEAE	<i>Celtis</i> spp.	2	2	2	6
INDETERMINABLE		0	0	3	0
TOTAL		2	3	5	7
Flot SQII QC					
LAMIACEAE	<i>Vitex</i> cf. <i>glabrata</i>	3	0	1	0
MALVACEAE	<i>Triumfetta</i> sp.	0	0	1	0
SOLANACEAE	<i>Solanum</i> spp.	2	0	1	0
ULMACEAE	<i>Celtis</i> spp.	0	0	5	1
VITACEAE	<i>Ampelocissus acetosa</i>	3	0	0	0
	<i>Cissus</i> cf. <i>adnata</i>	0	0	1	0
INDETERMINABLE		2	0	0	0
TOTAL		10	0	9	1

**Table 5.** Seeds per SU from each recovery context, expressed in both fragment counts (*n*) and percentage of total assemblage (%).

IDENTIFICATION		SU1		SU2		SU3		SU4	
FAMILY	TAXON	<i>N</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
LAMIACEAE	<i>Vitex</i> cf. <i>glabrata</i>	3	25.0	0	0	1	6.3	0	0
MALVACEAE	<i>Triumfetta</i> sp.	0	0.0	0	0	1	6.3	0	0
MELIACEAE	<i>Melia azedarach</i>	0	0.0	1	33.3	0	0	0	0
MORACEAE	<i>Ficus</i> sp.	0	0.0	0	0	0	0	1	9.1
SOLANACEAE	<i>Solanum</i> spp.	2	16.7	0	0	1	6.3	0	0
ULMACEAE	<i>Celtis</i> spp.	2	16.7	2	66.7	9	56.3	10	90.9
VITACEAE	<i>Ampelocissus acetosa</i>	3	25.0	0	0	0	0	0	0
	<i>Cissus</i> cf. <i>adnata</i>	0	0.0	0	0	1	6.3	0	0
INDETERMINABLE		2	16.7	0	0	3	18.8	0	0
TOTAL		12	100.0	3	100.0	16	100.0	11	100.0

fractions, were recovered from Mount Behn, 43 of which can be coordinated in secure stratigraphic contexts (Table 4, Table 5, Figure 6). Flotation proved beneficial and revealed five new taxa, belonging to four families, not recovered by sieve at the

site, *Ampelocissus acetosa*, *Cissus* cf. *adnata*, *Solanum* spp., *Triumfetta* sp. and *Vitex* cf. *glabrata*. Sieved remains, which are less diverse than the flot assemblages, are attributed to three families: Meliaceae, Moraceae and Ulmaceae. Overall, the most common taxon recovered is *Celtis* spp., the number of which increases with depth. Various *Celtis* species have been identified in the Kimberley, in particular *C. australiensis*, *C. philippensis* and *C. strychnoides* (Guymer 2013; Wheeler 1992). *C. australiensis* is no longer a current taxon name and so the *Celtis* spp. in this paper refers to *Celtis* endocarps which could be either *C. philippensis* or *C. strychnoides*. Minor contributions include: *Ampelocissus acetosa*, *Cissus* cf. *adnata*, *Cleome* cf. *viscosa*, *Ficus* sp., *Melia azedarach*, *Solanum* spp., *Triumfetta* sp. and *Vitex* cf. *glabrata*. The seeds and fruits show no signs of carbonisation. SU3 is the most taxon rich unit (five taxa), followed by SU1 (four taxa), while the SU2 and SU4 assemblages are comprised of two taxa each (*Celtis* spp. with *Melia azedarach* and *Ficus* sp., respectively).

## Discussion

### Archaeobotanical taphonomy at Mount Behn rockshelter

#### Wood charcoal vitrification, radial cracks and taphonomy

Vitrification is the process by which plant tissues fuse during combustion. When these anatomical elements fuse together, the charcoal or wood is more likely to survive in the archaeological record because there is less surface area available to biodegrade. By the same token, these fused anatomical features are obscure, rendering identification unlikely. Vitrified wood charcoal fragments ( $n = 1142/1513$ , 75.5%) dominate the Mount Behn anthracological record.

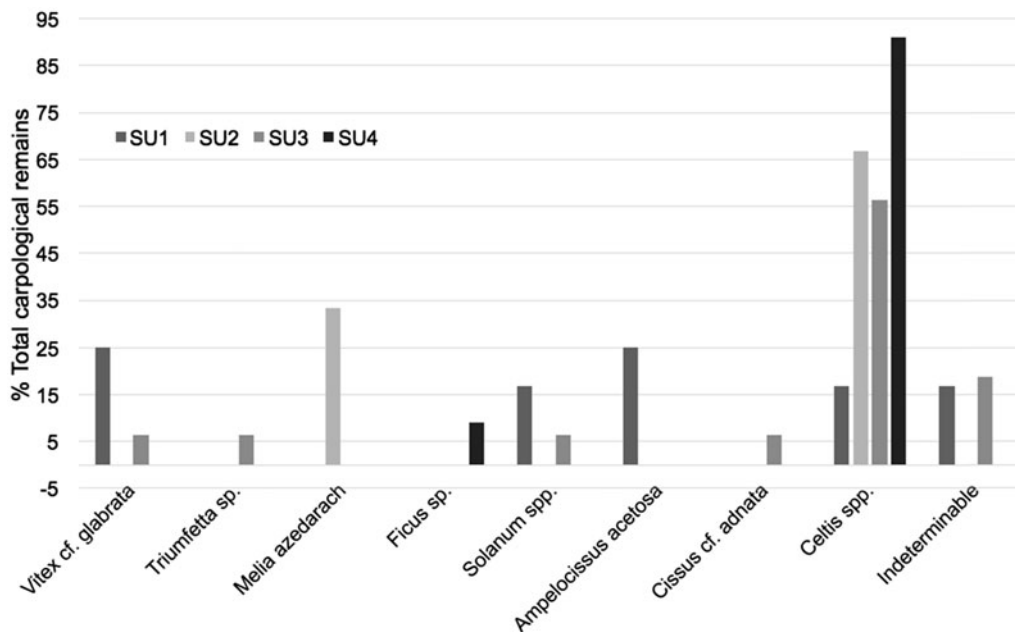


Figure 6. Seeds by SU.

At Mount Behn rockshelter, where preservation of botanics (and organics in general) is poor, it makes sense that the anthracological assemblage would be mostly comprised of vitrified charcoals that are more likely to survive post-depositional processes.

The degree of vitrification, which can vary within an individual sample, may range from low brilliance-refractiveness, where certain anatomical structures may still be visible, to a completely fused, refractive mass (Marguerie and Hunot 2007). The factors that produce vitrification in wood charcoal, which is different from the pressurised transformation of lignocellulosic tissues to vitrinite in coal petrology (Kaelin et al. 2006), are poorly understood. Researchers have put forward various hypotheses to explain the vitrification process, including the combustion of wood at high temperatures (Fabre 1996; Prior and Alvin 1983; Thinon 1992), burning of green wood (Scheel-Ybert 1998; Talon 1997; Thinon 1992), re-charring (Fabre 1996), the transformation of resin (McParland et al. 2010), a high silica content within wood, and rapid cooling of charcoal with quenching (for the last two causes see JISCMail Archaeobotany online discussion group, cited in McParland et al. 2010:2679). McParland et al. (2010) examined both archaeological and laboratory-experimental wood charcoal assemblages, and demonstrated that neither high temperatures nor burning of green wood were the sole factors behind the phenomenon of vitrification. It seems likely that several factors, which might occur before, during and after combustion, must act collectively on an assemblage to produce vitrified charcoals. Experimentation in both the laboratory and field is necessary to shed further light on the conditions that produce vitrification in wood

charcoal, in conjunction with detailed reporting of archaeological contexts where vitrified assemblages have been recovered.

The *Grevillea/Hakea* sp. charcoal type, which is very distinctive with its broad rays and festooned axial parenchyma, was often distinguishable despite vitrification (Figure 8(A,D)). Because the *Grevillea/Hakea* sp. charcoals were identifiable, despite vitrification, the higher proportion of *Grevillea/Hakea* sp. charcoals compared with other taxa is certainly an artefact of preservation. Other taxa were less distinguishable because of vitrification, with limited exceptions where vitrification was only partial on the fragment (Figure 8(B,C,E,F)).

Radial cracks (Figure 8(D)) were observed in the majority of vitrified *Grevillea/Hakea* sp. charcoals, in several non-vitrified Lamiaceae sp. twigs, but not the other indeterminable charcoals. The frequency of radial cracking, which is not uncommon in wood charcoal, is contingent on the density and size of the wood's rays, the proximity to the pith, the wood's moisture content prior to charring, and the temperature of combustion (Marguerie and Hunot 2007:1421; Prior and Alvin 1983; Théry-Parisot 2001; Théry-Parisot and Henry 2012). The broad, dense rays of *Grevillea/Hakea* sp. charcoals increase the likelihood of radial cracking, which is often associated with vitrification (Marguerie and Hunot 2007). The cracking of non-vitrified Lamiaceae sp. twigs, which have much narrower rays than the *Grevillea/Hakea* sp. charcoals, could be related to the dampness of the wood, or temperature of the fire when charred. Further experiments on these features would need to be conducted on Lamiaceae taxa in order to understand the combustion patterns of these woods in particular.



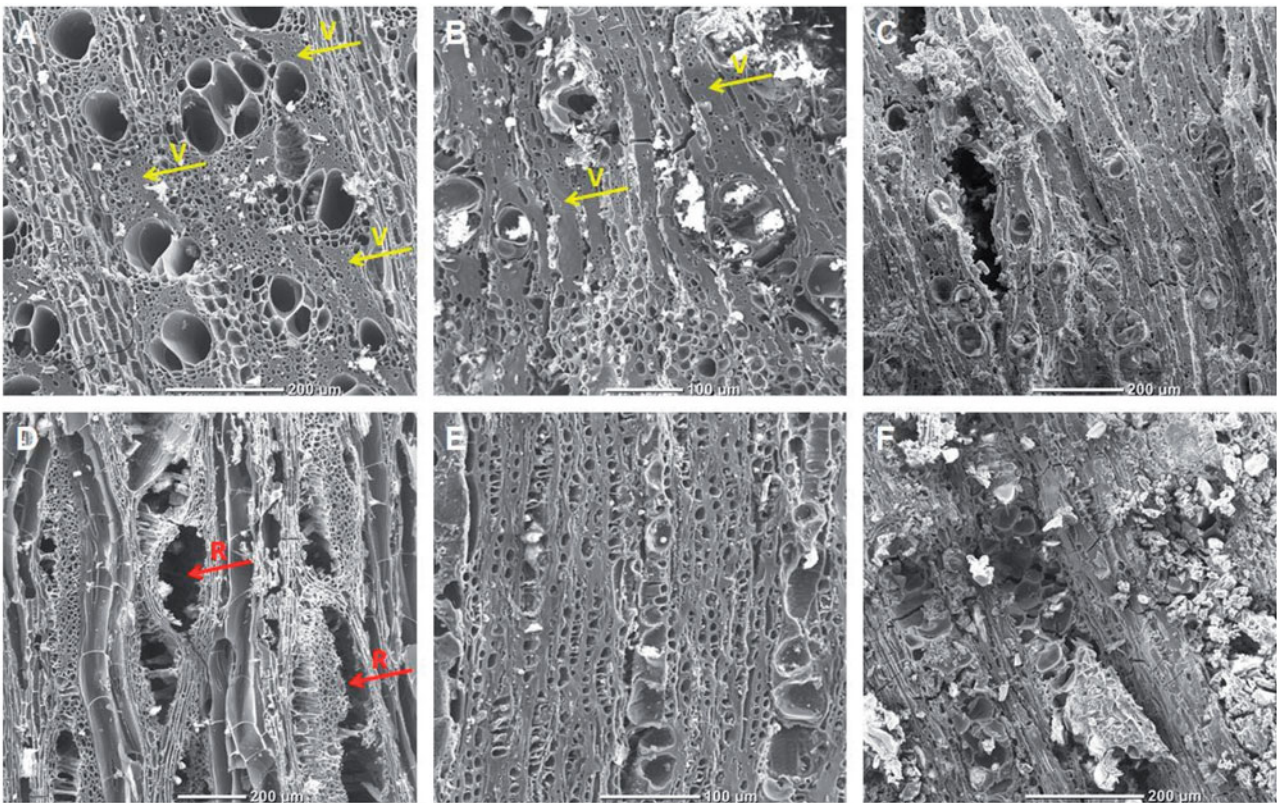
**Figure 7.** (A) *Celtis* spp. endocarps; (B) *Vitex* cf. *glabrata* drupes; (C) *Ficus* sp. fruit; (D) *Triumfetta* sp. Fruit; (E) *Cissus* cf. *adnata* seed; (F) *Solanum* sp. seed. All images taken by India Ella Dilkes-Hall using a Leica M205C stereomicroscope, with Leica Application Suite Version 3.8.5.

### Seed and fruit taphonomy

The carpological assemblage indicates a decrease of preservation of botanical materials with depth, the exception being *Celtis* spp., of which ten endocarps were recovered from SU4 (Table 5), which could reflect an intrusion of more recent material. *Celtis phillipensis* and *Celtis strychnoides* are widespread tropical shrub-tree species that grow across Northern Australia and are frequently concentrated within vine thicket communities (Kenneally et al. 1996; Wheeler 1992). *Celtis* spp. produce fleshy drupes with hard, stony endocarps, from January to May coinciding with the mid to late wet season (Kenneally et al. 1996). There are few references in the ethnographic literature for the use of *Celtis* species by Aboriginal groups, with only one reference

for the Kimberley region from the Bardi people, who eat the ripe fruit raw (Smith and Kalotas 1985). While *Celtis* endocarps are commonly recovered from archaeological sites in the Kimberley region, the high proportions in the Mount Behn record are unlikely to be linked to subsistence strategies.

The stony *Celtis* endocarps are globose with reticulate surface patterning, and are often recovered from archaeological contexts (Figure 7A; O'Connor et al. 2014; Sievers 2006; Wang et al. 1997). The robust *Celtis* sp. endocarp not only takes on atmospheric carbon (Wang et al. 1997) but is also subject to recrystallisation in a diagenesis similar to that observed in shells and coral, which increases their preservation potential (Messenger et al. 2010; O'Connor et al. 2014). The calcium carbonate enrichment process of *Celtis*



**Figure 8.** *Grevillea/Hakea* sp. type with vitrified fibres, examples of which are depicted with arrows, transverse section (A), tangential longitudinal section with radial cracks, examples of which are depicted with arrows (D); indeterminate charcoal with fibres that are more vitrified than (A), depicted with arrows, more transverse section (B), tangential longitudinal section (E); indeterminate charcoal mostly vitrified, transverse section (C), tangential longitudinal section (F) (all images of archaeological charcoals from Mount Behn rockshelter, scanned by Rose Whitau using the JEOL JCM-6000 Neoscope Scanning Electron Microscope (SEM) at the Archaeology and Natural History Department, Australian National University)

endocarps echoes the development of secondary carbonates observed around some bones at the microscopic level within the Mount Behn microstratigraphic sequence (Vannieuwenhuysse 2016) and demonstrates a certain degree of wetting/drying of the Mount Behn sequence at some time in the past or over a seasonal rhythm. Intense weathering and deposition of calcium carbonate flow layers are observed over the walls of the rockshelter and illustrate seasonal water infiltration.

#### **Other taphonomic considerations**

Aside from the fracturing produced by mechanical trampling, wood charcoal diagenesis at Mount Behn rockshelter is largely an effect of pre-depositional factors, while the preservation of seeds and fruits appears to be more affected by post-depositional processes. The fact that preservation of seeds diminishes with increasing depth is a normal evolution of the organic matter within stratigraphic profiles, especially when there is evidence of bioturbation as in the Mount Behn sequence. Interestingly, differential preservation between types of botanic remains was also observed at the microscopic level in the micromorphological assessment of the sequence (Vannieuwenhuysse 2016). For example, no macropod coprolite fragments

(formed of organic matter) were visible in this section, which is unexpected, particularly since macropod excrement and hollows were observed on the surface of the deposit. These particles are represented in the sequences of other sites of the region such as Carpenter's Gap 1 and Riwi, which are located within similar limestone environments (Vannieuwenhuysse 2016; Vannieuwenhuysse et al. 2017). Similarly, phytoliths, although composed of silica and therefore more robust than carbon based plant remains, were not observed in Mount Behn micromorphological thin sections (Vannieuwenhuysse 2016). This latter example could be explained either by the absence of primary deposition of such particles (absence of taxa producing phytoliths) or other taphonomic factors affecting their preservation over time.

#### **Sample richness and representativeness**

The taxon richness of the modern vegetation was not represented in either the wood charcoal or seed and fruit assemblages. At Mt Behn, 17 taxa from eight families (wood charcoal) and eight taxa from seven families (seeds) were identified at Mount Behn rockshelter, whereas at Riwi, which is some 300 km southeast of Mount Behn rockshelter, bordering the Great Sandy Desert, supporting a much

lower species richness of modern vegetation, 19 taxa from 10 families (wood charcoal) and 34 taxa from 17 families (seeds and other floristics) were identified (Figure 1; Dilkes-Hall 2014; Whitau et al. 2016a, 2017). At Mt Behn rockshelter, SU1, the youngest unit, which has the lowest proportion of vitrified charcoals, has the highest taxon richness. SU4, which has the highest proportion of both vitrified and indeterminate charcoals, still has a relatively high taxon richness, suggesting that the taxa that are represented would have been in higher proportions within the original assemblage of fuel wood.

The dominant taxa from the wood charcoal and seed assemblages are *Grevillea/Hakea* and *Celtis* spp., respectively. Neither *Grevillea* nor *Hakea* species, which produce woody seed pods, were recovered in the seed record and *Celtis* sp. was not recovered in the anthracological record. *Grevillea* and *Hakea* are widespread genera on the Australian continent, with a high proportion of species level diversity, which range from small shrubs to tall trees, and occupy a vast tract of habitat types. The prevalence of *Celtis* spp. is most likely to be due to the inclusion of more recent material or an artefact of preservation, with mineralization producing a less degradable endocarp. In addition, the abundance of *Celtis* could be an effect of modern or prehistoric environmental seed rain from the natural accumulation of seeds in the shelter given that *Celtis* often grows on limestone outcrops (Minnis 1981), and indeed several *C. strychnoides* trees and shrubs currently occupy the entrance to Mount Behn rockshelter.

The dominance of *Grevillea/Hakea* sp. wood charcoal in the Mount Behn rockshelter anthracological assemblage is an artefact of positive preservation. The characteristics of Proteaceae anatomy, compared to other woods common to Northern Australia, are distinctive even when the wood charcoal is vitrified, and are thus more likely to be identified than other taxa. Table 3 shows that if the vitrified *Grevillea/Hakea* sp. charcoals were, like 98.8% ( $n = 829/839$ ) of the other vitrified charcoals, indeterminate, the proportions of *Grevillea/Hakea* sp. would be low, forming a subsidiary component after *Eucalyptus* sp. in SU1, SU3, and SU4, while only one fragment of non-vitrified *Grevillea/Hakea* sp. was recovered from SU2. Indeed, if vitrified *Grevillea/Hakea* sp. charcoals are removed from the equation, *Melaleuca* sp. becomes the dominant taxon for SU4, *Eucalyptus* sp. for SU3 and SU1, while two fragments of Lamiaceae sp. would comprise the dominant component of the smaller SU2 assemblage. Therefore, while *Grevillea/Hakea* sp. charcoals dominate the wood charcoal record, if other vitrified charcoals were able to be identified, it is likely that *Grevillea/Hakea* sp. charcoals would form a subsidiary component across the assemblages.

### **People, climate, and vegetation at Mount Behn rockshelter**

In terms of the broader climate signal, the stable isotope profile of the KNI-51 speleothem shows an abrupt weakening of the monsoon around 4.2 ka, which is sustained until 1.2 ka, with a peak in aridity occurring between 1.5 and 1.2 ka (Denniston et al. 2013). At Black Springs, a sharp decline in organic content, increased aeolian sedimentation, a shift in vegetation with lower aquatic species, and the lowest humification values for the core illustrate the driest phase for the record between 2.6 and 1.3 ka (Field et al. 2017; McGowan et al. 2012). According to other records therefore, SU4–SU3 (2825–1750 cal BP) was deposited during a period of relative aridity. By contrast, SU1 (439–0 cal BP) was deposited during wetter conditions, with evidence for small-scale variability, occurring from within the last millennium through to the present (Denniston et al. 2013; Field et al. 2017; Proske 2016).

Unfortunately, the taxon richness of the modern vegetation is not represented in the anthracological record at Mount Behn rockshelter, precluding the application of wood charcoal for palaeoenvironmental reconstruction (Asouti and Austin 2005; Dotte-Sarout et al. 2015). However, the wood charcoal and seed results show that different habitats were exploited throughout the site's occupation: the eucalypt savanna of the valley floor, the dry rainforest taxa of the limestone escarpment, and riparian vegetation are each represented throughout time. The major exception is the SU2 assemblage, which is further limited by the low volume of the SU. The low number of recovered remains prevents examination of the preference for each of these landscape types and how these preferences might have changed alongside the adaptation of vegetation communities to climate change over time. However, the fact that each vegetation type is represented is not insignificant, and illustrates that localised vegetation communities and the people who exploit them might not have been affected to the extent suggested by the aridity suggested by the broader climate signal. Indeed, the fact that people continued to exploit each landscape type during a climatically arid phase could indicate that the area surrounding Mount Behn rockshelter was a refugium during this period (2,825–1,750 cal BP).

### **Resource management: the curious case of Proteaceae**

While few anthracological investigations have been conducted in Australia (cf. Dotte-Sarout et al. 2015), the handful that have been conducted in Western Australia (Byrne et al. 2013; Dotte-Sarout and Byrne



**Figure 9.** (A) *Grevillea/Hakea* sp. artefact fragment from Riwi Cave; (B) Wood shavings from Riwi Cave; (C) Boomerang stencil from Mount Behn rockshelter (A and B photographs taken by Michelle C. Langley and reproduced from Whitau et al. 2016b; C photograph taken by Jane Fyfe).

2013; Frawley 2009; Whitau et al. 2016a), with the exception of Frawley (2009), show that *Grevillea/Hakea* sp. woods were avoided for fuel use. In Weld Range *Grevillea* sp. trees are frequently distributed, growing as tall trees, which today are reserved for carving wooden tools and avoided for fuel as the wood does not burn well (Byrne et al. 2013). Zero fragments of *Grevillea/Hakea* sp. were identified from the Weld Range anthracological assemblage (Byrne et al. 2013). At Riwi Cave in the southern Kimberley, southeast of Mount Behn rockshelter, only two fragments of 3,142 analysed charcoals were identified as *Grevillea/Hakea* sp. (Whitau et al. 2016a). However, a 600-year-old wooden artefact fragment, imaged using X-ray microtomography, was identified as *Grevillea/Hakea* sp. (Figure 9(A); Whitau et al. 2016b). *Grevillea/Hakea* taxa, which grow as short shrubs on the Riwi limestone outcrops, are infrequently distributed amongst the modern vegetation. The low occurrence of recovered *Grevillea/Hakea* sp. charcoals, combined with the selection of the wood for artefact manufacture, can be argued to be an example of both specific site

collection and resource management at Riwi, since the infrequently distributed shrub might have been avoided for fuel wood if it was a valuable resource for wooden artefact manufacture (Whitau et al. 2016a, 2016b). In the Pilbara, where *Grevillea* and *Hakea* species tend to grow as short shrubs, zero Proteaceae fragments were also recovered in the anthracological assemblages (Dotte-Sarout and Byrne 2013). At Carpenter's Gap 1 rockshelter, located 40 km northwest of Mount Behn, Frawley (2009) was surprised to find an abundance of Proteaceae charcoals because beefwood (*Grevillea* sp.) is cited as a poor fuel wood, which burns quickly and does not retain its heat. The total number of Proteaceae identified is 46 fragments, with 18 occurring in the Holocene units (Frawley 2009).

While the dominance of *Grevillea/Hakea* sp. charcoals within Mount Behn anthracological assemblage is readily explained as an outcome of uneven preservation and identification bias, its abundance relative to other Western Australian investigations merits some discussion. To summarise the above, arguments for *Grevillea/Hakea* sp. avoidance have

included resource management for the production of wooden artefacts and its poor fuel capability.

At Carpenter's Gap 1, while no wooden artefacts were recovered, wood shavings, very similar to those found at Riwi, were recovered throughout the deposit (Figure 9(B)). No wooden artefacts or wood shavings were recovered from Mount Behn rockshelter, an anticipated probability given both the poor botanic preservation at the shelter and the limited recovery of wooden artefacts in Australia in general (cf. Whitau et al. 2016b). However, plant-based technologies are painted and stencilled on the shelter walls, including several stencils of boomerangs and an axe, which at the very least indicates the presence of such technologies at the site (Figure 9(C)). The evidence for woodworking is certainly less definitive at Mount Behn rockshelter than Carpenter's Gap 1 or Riwi; however, it is worth noting that wood tends to be worked when green, and green wood, particularly a resinous wood like those produced within the *Grevillea* and *Hakea* genera, is more likely to both vitrify and radially crack (Marguerie and Hunot 2007). The abundance of vitrified, radially cracked *Grevillea/Hakea* sp. charcoals could represent the incidental by-products of artefact manufacture. Finally, it is possible that in areas of higher taxon richness of woody taxa, there is no need to be selective with wood resources, which would explain why Proteaceae was recovered at both Carpenter's Gap 1 and Mount Behn rockshelters, which have a higher density and species richness of woody taxa than other sites mentioned here.

Outside of Western Australia, in the Northern Territory's tropical Kakadu region, anthracological analysis was conducted on 14 hearths excavated from the Madjedbebe archaeological site (Figure 1; Carah 2016). Taxa from open eucalypt woodland and monsoon vine forest dominate the anthracological assemblages, with minor contributions of *Grevillea/Banksia* shrubland averaging 3.84% frequency across the seven hearths in which this taxon appears (Carah 2016). *Grevillea/Banksia* wood charcoal was recovered from all the late Holocene hearths with the exception of one (C4/9A); from three late Holocene/LGM hearths (D2/21A, E3/20A, E4/22A); and was not recovered at all from any of the pre LGM hearths at Madjedbebe (Carah 2016). The hearths of the late Holocene have the highest taxon richness of the Madjedbebe anthracological assemblages both individually and collectively, and the E4/22A hearth has the highest taxon richness of the Pleistocene hearths. This supports the hypothesis presented here that, unsurprisingly, in areas of higher taxon richness of woody taxa, there is less need to be selective with wood resources, than areas of lower taxon richness, such as Riwi. Indeed, Jones et al. (2011) note that *Grevillea striata* is used in the

Bradshaw and Judbarra parks area of Northern Territory for both carving and fuel.

However, the D2/21A and E3/20A hearths, alongside the other early Holocene/LGM hearths, have a lower overall taxon richness than the pre LGM group, and yet the frequency of *Grevillea/Banksia* wood charcoal is the highest for this unit (9.70%) (Carah 2016). Carah (2016) argues that the increase of this taxon during this time could be a reflection of environmental changes following the end of the LGM and the re-activation of the summer monsoon, and that the low incidence of *Grevillea/Banksia* shrubland in the older units compared to its presence in all four of the most recent hearths could suggest that this vegetation type was limited in distribution in the local environment during the Pleistocene. Carah (2016) further argues that because the *Grevillea/Banksia* community grows in poorly drained depressions, this limited distribution could indicate lower precipitation during the Pleistocene, and an increase in freshwater availability in the late Holocene, with the latter point supported by the Madjedbebe pollen record.

## Conclusions

While the limited survival of macrobotanical remains at Mount Behn rockshelter did not allow for a valid palaeoenvironmental reconstruction, nor a direct testing of Maloney et al.'s (2017) foraging hypothesis, the recovered materials did show that various habitats (savanna, riverbanks, limestone outcrops) were exploited throughout the site's occupation sequence. The fact that each vegetation type is represented illustrates that localised vegetation communities and the people who exploited them might not have been affected to the extent suggested by the broader climate. The relationship between people, plants, and climate change needs to be explored at relevant scales, a point to be considered when inferring foraging risks extrapolated from a palaeoclimate record located at some spatio-temporal distance from the site under discussion.

The wood charcoal, seed, and fruit remains from Mount Behn rockshelter, like any archaeological assemblage, are artefacts of preservation; pre- and post-depositional factors have favoured the preservation of Proteaceae wood charcoal and *Celtis* endocarps, respectively. The complex factors that control the preservation of botanic remains ought to be borne in mind when interpreting all archaeobotanical assemblages, which the Mount Behn macrobotanical analyses clearly demonstrate. We are also beginning to see how exploitation of plant resources varies between archaeological sites, in comparison with other archaeobotanical records that are slowly being built up across the northern region of

Australia. If regional reference collections continue to be expanded, and field techniques adopted such as the simple bucket flotation used here, even poorly preserved plant assemblages, such as those recovered from Mount Behn rockshelter, will contribute to our understanding of human-environment interaction.

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## Appendix 1

Anatomical descriptions of archaeological wood charcoal types.

Taxon	Porosity	Vessel elements	Fibres/tracheids	Axial parenchyma	Radial parenchyma
<i>Terminalia</i> sp. COMBRETACEAE	Diffuse	Clusters 2–3 Weak tangential to diagonal Bordered to scalariform small pits	Fibre walls very thick	Paratracheal confluent Lozenge aliform Short bands (2–4 cells wide) Apotracheal aggregates	Uni to 4- seriate 6–23 cells high
<i>Acacia</i> sp. FABACEAE	Diffuse	Clusters 2–3 Weak tangential to diagonal Vestured pits	Fibre walls thick	Lozenge aliform Confluent Winged aliform Vasicentric	Uni to bi seriate 2–20 cells high Heterogenous
<i>Bauhinia</i> sp. FABACEAE	Diffuse	2 pore size classes Clusters 2 (large) Radial groups (1 large, 2–6 smaller) Weak diagonal to tan- gential Simple, small pits	Fibre walls thick	Scalariform bands (2–4 cells wide) Vasicentric Winged aliform Confluent Storied strands (2–4 cells long)	Uni to tri seriate 2–15 cells high Storied Heterogenous Procumbent body 1–2 rows upright/square
<i>Gyrocarpus</i> sp. HERNANDIACEAE	Diffuse	Clusters 2–3 Diagonal/weak tangential Bordered to scalariform, minute pits Plates simple	Fibre walls very thin	Paratracheal aggregates Apotracheal aggregates	Uni to tri seriate 2–15 cells high
<i>Clerodendrum/Vitex</i> sp. LAMIACEAE	Diffuse, growth boundary sometimes distinct	Radial groups 2–3 Tangential bands Radial/diagonal lower density Bordered to scalariform, minute pits	Fibre walls thick	Scarce Scanty paratracheal	1–4 seriate 6–40 cells high 2 sizes Tile cells Heterogenous Procumbent body, 2–4 rows of upright/square
<i>Ficus</i> sp. MORACEAE	Diffuse	Radial groups 2–4 Diagonal/radial Bordered to scalariform, small pits Simple plates	Fibre walls thick to very thick	Bands >4 cells (4–10) Bands <4 cells (2–4) Scanty paratracheal	Uni to 4- seriate 6–25+ cells high Heterogenous Procumbent body 1–3 rows upright/square Tile cells
<i>Corymbia</i> sp. MYRTACEAE	Diffuse	Clusters 2–6 Dendritic to diagonal Tyloses abundant Vestured, minute/small pits Plates simple	Fibre walls thin to medium Distinctly bordered pits	Confluent Winged aliform Wavy bands (1–3 cells wide) Strands 2–4 cells long	Uni to biseriate 2–9 cells high Homogenous Procumbent
<i>Eucalyptus</i> sp. MYRTACEAE	Diffuse, with abrupt change in pore density	Clusters 2 Strong diagonals Vestured, small/medium pits Plates simple	Fibre walls medium to thick Distinctly bordered pits	Abundant apotracheal aggregates Paratracheal aggregates Vasicentric	Uni to biseriate 2 to 10 cells high
<i>Melaleuca</i> sp. MYRTACEAE	Diffuse	Mostly solitary Diagonal to radial Vestured change- able pits	Fibre walls medium Distinctly bordered pits	Scarce apotracheal aggregates Scanty paratracheal	Uni to biseriate 1–13 cells high
<i>Flueggea</i> sp. PHYLLANTHACEAE	Diffuse	Radial chains 2–6 (8–12) Radial Bordered to scalariform, very minute pits	Fibre walls very thick	Abundant apotracheal aggregates Paratracheal aggregates	Uni to tri seriate 3–23 cells high Tile cells
<i>Grevillea/Hakea</i> sp. PROTEACEAE	Diffuse	Clusters 2 Tangential (+weak diag- onal), festooned Scalariform to bordered, minute pits Plates simple	Fibre walls thick to very thick Simple to minutely bor- dered pits	Festooned, confluent Lozenge/winged aliform Fusiform parenchyma cells	Rays of 2 sizes Uni to triseriate, 4–13 cells high 10–14 seriate, 100+ cells high