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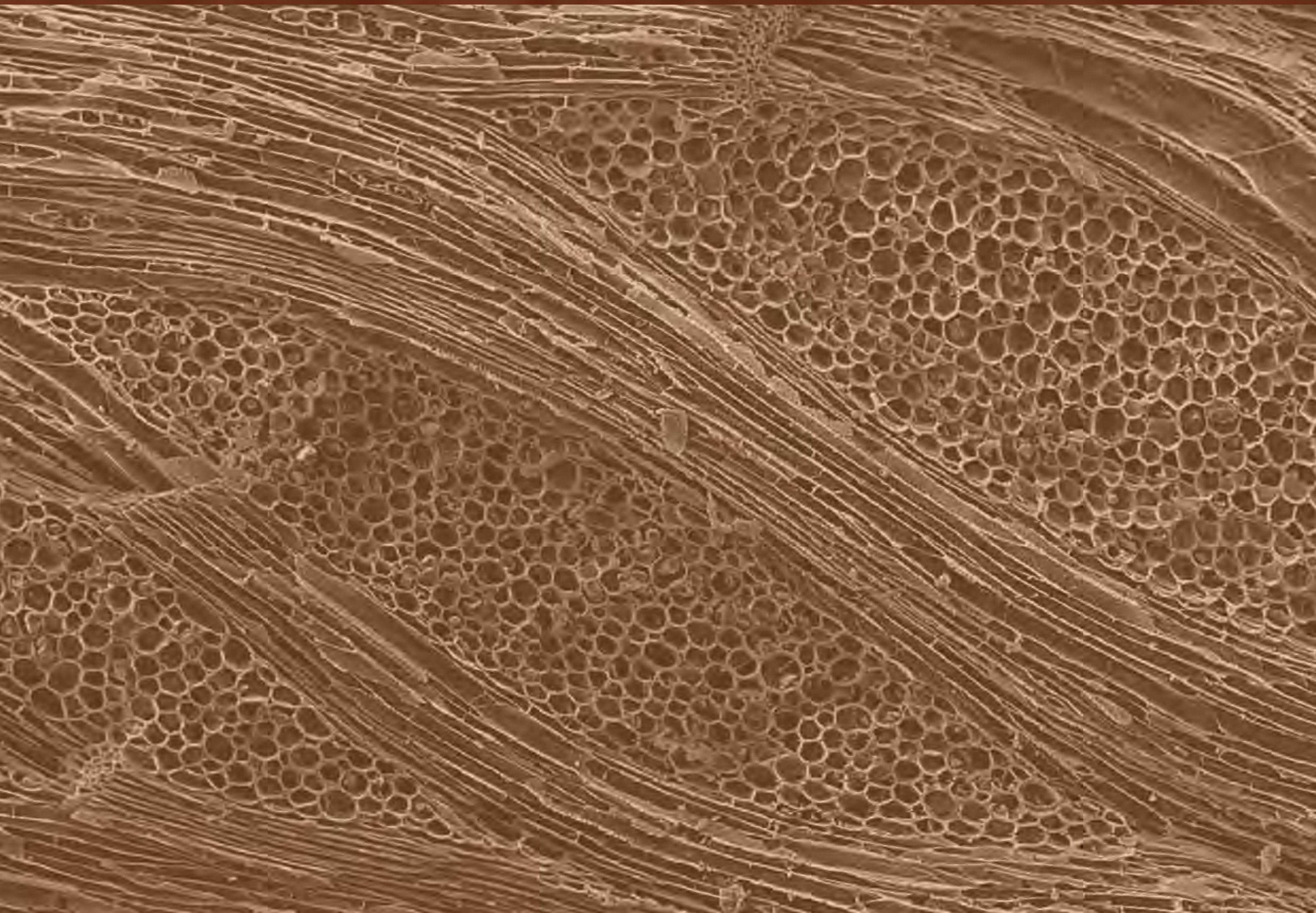

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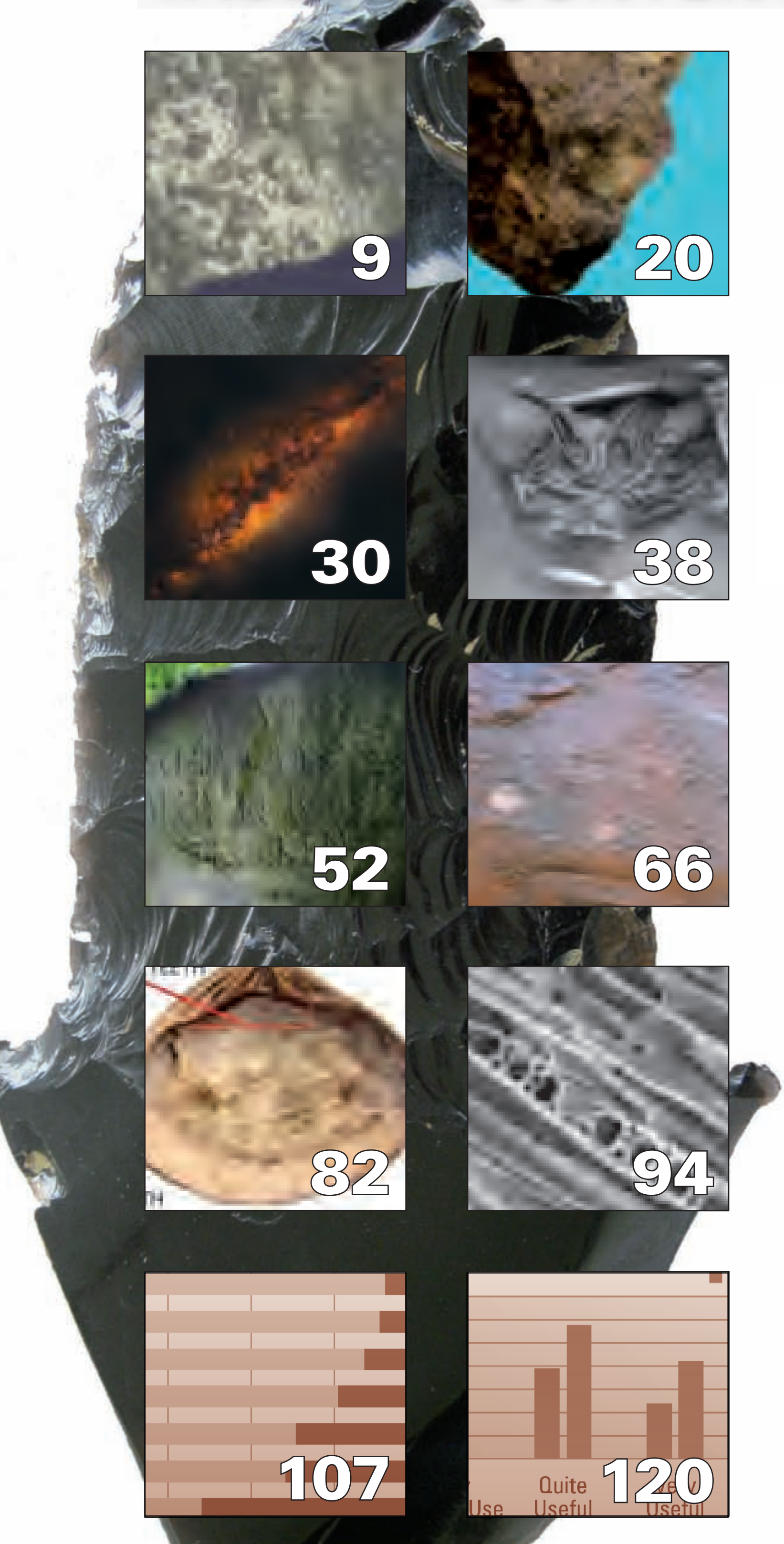

Credits from top: Barema 1 stemmed tool (photograph by Peter White); Polish on a chalcedony experimental artefact (photograph by Laressa Beherowyj); Large burin blade core from Bapton Paddock 1 (photograph by Grant Cochrane); The 'Emu in the Sky' (image reproduced courtesy of Barnaby Norris); Burial 1, Gillman Mound; Inscription left by crew of VOC ship *Ter Veere* in 1632, Nosy Mangabé, Madagascar (photograph by Mark E. Polzer); Example of a Calvert Ranges Archaic Face; Measured attributes of *A. striata*; SEM photographs *Acacia tetragonophylla*; Digital tools rated according to their desirability by respondents'; 'Keeping Country' Course webpage.

Credits: Excavation at Long Point, Coorong (photograph by Lynley Wallis).

CHARCOALS AS INDICATORS OF ANCIENT TREE AND FUEL STRATEGIES:

An application of anthracology in the Australian Midwest

Chae Byrne[1] (nee Taylor), Emilie Dotte-Sarout[2] and Vicky Winton[2]

Abstract

Anthracology (charcoal analysis) can inform about palaeoenvironments and human choices concerning the use of wood resources. While charcoal is commonly recovered during excavations, anthracology is poorly developed in Australian archaeology. This paper presents the first application of anthracology in the Midwest of Western Australia, at the Weld-RS-0731 (WA Department of Aboriginal Affairs Site ID 28793) site in the Weld Range. It uses methodological approaches developed by European anthracologists but not previously applied to Australian charcoal assemblages. The diversity and frequency of taxa identified in the late Holocene Weld-RS-0731 charcoal assemblages correspond to known vegetation communities, similar to those found in the area today. Nevertheless, the assemblages' compositions demonstrate the targeting of specific habitats, as well as the purposeful selection and avoidance of certain taxa. Our results confirm that wood gathering was not a separate specialist activity, but likely occurred alongside other subsistence tasks.

Introduction

Archaeobotany is the study of plant remains (both micro- and macroscopic) from archaeological contexts. As a subdiscipline of archaeobotany, anthracology aims to determine environmental and ethnobotanical histories based on the taxonomic identification of macroscopic charcoal fragments. By exploring the frequency and diversity of taxa represented in anthracological assemblages from stratified contexts it is possible to identify the plants used in the past by site occupants for fire fuel, as well as to reconstruct a palaeoenvironmental history (Picornell et al. 2011; Shackleton and Prins 1992:623; Théry-Parisot et al. 2010). Fundamental sampling methodologies and analytical principles have been developed, mainly in Europe, but have rarely been adopted in relation to Australian material (for recent reviews see Asouti and Austin 2005; Théry-Parisot et al. 2010). The research presented herein was conducted as a pilot study applying these methods and principles to samples derived from excavations at the Weld-RS-0731 site in the Weld Range, in the Midwest region of Western Australia (WA). The research was conducted by Eureka Archaeological Research and Consulting, UWA (Taylor 2012).

Despite the critical role that plants have played in human economies through time, anthracological investigations are often underutilised or non-existent in Australian archaeological investigations (Denham et al. 2009; but see Burke 2004, Carah 2010, Dortch 2004 and Edgar 2001 for exceptions); charcoal analysis has never previously been carried out in the Midwest. Nevertheless, two case studies from other parts of Australia are directly relevant to this study: that by Smith et al. (1995) at the Puritjarra rockshelter in arid Central Australia, and another by O'Connor and Frawley (2010) at Carpenters Gap 1 in the sub-tropical Kimberley. Each study revealed the high potential of the approach, despite their small sample sizes (at Puritjarra ca 40–50 charcoal fragments from three time periods were examined, and 179 fragments over 17 excavation units were analysed at Carpenters Gap 1). While the minimum number of fragments required for valid analysis is debated, it is commonly argued that a minimum of 200 to 300 fragments per stratigraphic unit or archaeological context are required for a valid representation of the relative frequencies of taxa (Asouti and Austin 2005; Chabal et al. 1999; Scheel-Ybert 2002; Théry-Parisot et al. 2010). Even though charcoal analyses at Puritjarra and Carpenters Gap 1 did not meet these sampling thresholds, both studies identified important patterns. Anthracological analysis of Carpenters Gap 1 showed vegetation changes correlating with changes in the known palaeoclimatic record (O'Connor and Frawley 2010:317–319). Charcoal analysis for Puritjarra indicated fuel choice and revealed past occupants' movements within the landscape (Smith et al. 1995:174). Importantly, both studies identified the possible targeting of riverine or creek-line vegetation communities for firewood collection (O'Connor and Frawley 2010:318; Smith et al. 1995:176), as well as highlighting the importance of creating local reference collections to aid accurate identifications.

Anthracology uses the 'Principle of Least Effort' (PLE), a theoretical premise developed from ethnographic data (Asouti and Austin 2005; Picornell et al. 2011; Shackleton and Prins 1992). In the context of anthracological analyses, the central tenets of PLE are that people habitually burn what is both (a) easily accessible, and (b) of acceptable quality. This assumes that the woody taxa available around a site will be represented in the archaeological charcoal assemblage in direct proportion to their relative frequency in the local vegetation community. The local availability of different *acceptable* fire-fuel taxa is thought to vary with changes in vegetation communities over time (Figueiral 1996). Anomalies—i.e. over-representation, under-representation or absence of taxa—can be identified as anthropogenic choices (targeting or avoidance), hence allowing for ethnobotanical inferences. If valid sampling methodologies are followed, vegetation communities can be identified through taxa rank and taxonomic composition and, in turn, this allows for interpretations concerning daily paths of movements through the landscape or activities associated with wood gathering.

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Distances and considerations of what is located within the 'surrounding' environment of a site will depend on parameters such as the landform and environmental variables, the type of occupation represented at a site, and the local socio-economic system of the people occupying this site. Therefore, the vegetation radius represented by charcoal assemblages should not be considered as predictable or known, but rather as one of the questions that can be investigated using anthracology.

Consequently, the aim of this research was to determine the taxa used for fire fuel by past occupants of the Weld Range, to explore resource management behaviours, such as taxa selection or specific habitat targeting, and to understand people's daily paths of movements, while also reconstructing past vegetation cover. The project also aimed to establish whether modern anthracological methods from elsewhere can be used successfully in the context of arid Australia; this was investigated through a case study focusing on two charcoal assemblages from the Weld-RS-0731 site.

Environmental and Cultural Setting

The Weld Range lies within the upper Murchison Botanical District of the Eremaean Botanical Province (Figure 1). The steep hills and valleys of the Range extend in a southwest to northeast alignment for 60 km, with a maximum width of 4 km (Savage and Dennison 2007:12). The Range is part of a series of greenstone ridges (Ecologia 2010:8) and provides plentiful outcrops of rock suitable for stone tool-making (e.g. banded ironstone formation [BIF], jaspilite, chert, dolerite, quartz). While substantial downpours can occur, annual rainfall is low, averaging 236 mm per year (Bureau of Meteorology 2011), and drains north into the Murchison River system, or south into inland salt lake systems of the Western Plateau (Ecologia 2010). A number of claypans are present locally and the presence of standing water for some parts for the year would have added to its attractiveness and feasibility of past human occupation.

Whilst the Range represents a small proportion of the Murchison bioregion, its unique geology and soils, combined with its isolation, has produced distinctive vegetation communities (Ecologia 2010:21) housing over 830 vascular plant species (Curry et al. 1994:1). Seven main vegetation communities are recognised in the vicinity of Weld-RS-0731, but in particular, the hillside around the site supports a community of *Acacia* species, with mulga (*A. aneura)* shrublands being the predominant vegetation type within the region today (see Table 1, after Ecologia 2010; see also Beard 1968, 1976).

Weld-RS-0731 is located on the northern flank of the Range, approximately half-way up the hillslope, at an altitude of 540 m above sea level and 70 m above the open flats to the north (Figure 2). The site is a prominent landscape feature, visible for many kilometres as one approaches from the north.

Within a 2 km radius of Weld-RS-0731, 12 surface artefact concentrations, two rockshelters, two artefact concentrations associated with stone quarries, one quarry and one artefact concentration with a scarred tree have been recorded during mining-associated heritage surveys. Within the immediate vicinity of Weld-RS-0731, the context, frequency and density of artefact concentrations indicates that the low-lying areas between ephemeral, north draining creek-lines were the focus of past Aboriginal subsistence activities, with people using the hills and valleys of the Range, including Weld-RS-0731, perhaps for more task specific activities. To the northwest of Weld-RS-0731, artefact concentrations occur in association with what Wajarri Traditional Owners call 'the food bowl', named in recognition of its central role as a traditional foraging and hunting ground, camping area and water-source. The food bowl is an ecologically diverse, low-lying claypan extending over more than 6 km northwest-southeast and 4 km east-west.

In a wider landscape context, the occupation of Weld-RS-0731 is demonstrably linked to the use of at least one other culturally significant place in the Range. Ochre used to produce hand-stencils at Weld-RS-0731, and a fragment of ochre recovered from the excavation have been sourced using trace element chemistry to the Nationally Heritage listed site of Little Wilgie Ochre Mine, as opposed to its more famous neighbour, Wilgie Mia, whose ochre has distinctly different trace element chemistry (this research is to be published elsewhere).

The Weld-RS-0731 Rockshelter Excavations and Anthracological Sampling

This study uses archaeological assemblages of wood charcoal recovered from a 1 x 1 m excavation at Weld-RS-0731 (WA Department of Aboriginal Affairs Site ID 28793) undertaken in 2011 as part of a wider study of the occupation of the Weld Range and past use of ochre from the Wilgie Mia and Little Wilgie Aboriginal ochre mines. The north-facing shelter measures approximately 12 m wide, 2.5 m deep and 2.5 m high.

Excavation, using arbitrary excavation units of approximately 3 cm depth where no stratigraphic horizons were evident, extended to a depth of approximately 40 cm below surface without reaching bedrock (Figure 3); unfortunately, it was not possible to continue the excavation owing to time constraints. Where small finds and large fragments of charcoal were encountered in situ these were plotted, uniquely identified and individually bagged. All excavated sediment was weighed and sieved through nested 6 and 3 mm sieves. All sieve residues were retained and returned to the laboratory, where the bulk of the light fraction was separated from the residue by flotation.

The excavated sediment was a clay-sand matrix with inclusions of spherical, angular granules through to cobbles of rock, as well as charcoal and stone artefacts. The pH ranged from 4.5–5.5 and, given this, it is not surprising that just 7.2 g of fragmentary bone were recovered. Similarly, very few wood (25.8 g), seeds (6.6 g) or non-woody plant macrofossils

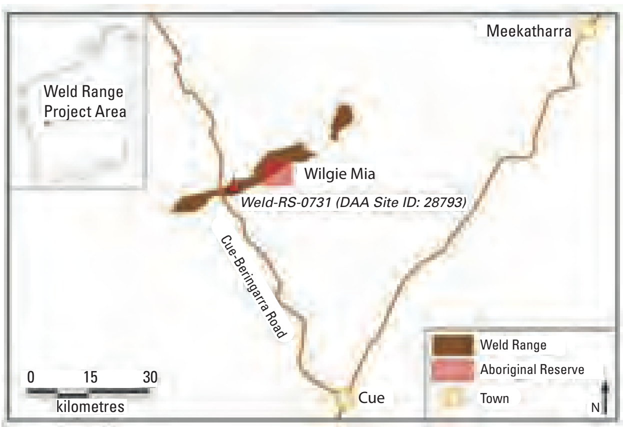

Figure 1 Location of the Weld Range (courtesy of Viv Brown).

Articles

(25.0 g) were recovered. As such, there is extremely limited scope either for plant macro-analysis, other than wood charcoal, or for faunal analysis. However, the presence and preservation of pollen, phytoliths and DNA within the retained bulk samples is yet to be tested. The frequency of charcoal fragments was the most variable feature of the excavated sediments and Excavation Units (XUs) 9a, 9b, 12a, 12b, 12c, 13a, 13b and 13c were sub-units differentiated by their relative frequency of charcoal.

There were two stratified charcoal features clearly visible in the east stratigraphic section, (Figure 3). The upper lens was 10–15 cm below surface (bs), and was excavated in two successive excavation units across the 1 x 1 m square. Charcoal from this feature was AMS radiocarbon dated to 470–310 cal. BP (WK-32137) (Table 2). The lower charcoal feature was situated 25–35 cm bs and was represented only as densely packed charcoal with no scattered charcoal; it was dated to 4155–3920 cal. BP (WK-32138) (Table 2). The location of the charcoal features, within the drip-line of the rockshelter and in association with cultural materials, strongly indicated that they were not the remnants of natural bush fire events.

Anthracological assemblages were defined in relation to coherent archaeological events rather than artificial excavation units (cf. Chabal et al. 1999; Théry-Parisot et al. 2010); hence, in this study the two 'assemblages' relate to the two charcoal features and the associated dispersed charcoal fragments surrounding the upper feature.

The distinction between concentrated hearth material and scattered charcoal from around a hearth is important analytically, since dense charcoal tends to represent single or very few firing episodes (especially given the general habit of cleaning fire places between uses), whilst scattered charcoal tends to represent trampling of the remnants of multiple fires and hence multiple wood collection events. Consequently, anthracological practice requires sampling and analysis of both charcoal concentrations and scattered charcoal from occupation deposits to produce assemblages which, together, are more representative of the local environment (Chabal et al. 1999: Scheel-Ybert 2002; Théry-Parisot et al. 2010).

Vegetation Community	Associated Woody Species	Habitat
Acacia aneura low woodland over mixed open shrubs	*Acacia aneura* var. *aneura, A. aneura* var. *microcarpa, A. cockertoniana, A. ramulosa* var. *linophylla, Eremophila* spp.	Widely distributed across BIF ranges, mostly covering mid- to upper slopes and outcrops
Acacia aneura sparse shrubland over *Ptilotus obovatus* low shrubland	*Acacia aneura* var. *microcarpa, A. pruinocarpa, A. aneura* var. *aneura, A. aneura* var. *tenuis, Dodonaea pachyneura, Eremophila glutinosa, E. latrobei* subsp. *latrobei*	Ridge tops and upper slopes of higher elevation BIF ridges
Acacia spp. shrubland over open mixed shrub species and tussock grasses	*Acacia ramulosa* var. *linophylla, A. aneura* var. *aneura, Eremophila* spp.	Most widespread community occurring across sand plains and minor drainage areas, drainage areas, outwash plains and footslopes of hills
Acacia sp. Weld Range shrubland over mixed open shrubs	*Acacia* sp. *Weld Range, A. aneura* var. *microcarpa, A. speckii, A. tetragonophylla, Eremophila* spp., *Grevillea inconspicua*	Scree slopes of granite and dolerite, drainage lines
Acacia craspedocarpa open shrubland over open low shrubs	*Acacia aneura* var. *aneura, A. tetragonophylla, A. craspedocarpa, Grevillea striata, G. nematophylla* subsp. *supralunar*	Salt-affected, low lying and riparian areas
Mixed open chenopod shrubland	*Acacia aneura* var. *microcarpa, A. aneura* var. *tenuis, A. burkittii, A. craspedocarpa, A. tetragonophylla, Eremophila maculata* subsp. *brevifolia, E. latrobei* subsp. *latrobei*	Adjacent to seasonally inundated salt lakes, saline affected drainage lines and undulating plains
Halophytic shrubland	*Melaleuca stereophloia, Cratystylis subspinescens, Eremophila glabra* subsp. *glabra, Eucalyptus trivalva, E. carnei, Eremophila glabra* subsp. *glabra*	Saline claypans and seasonally inundated wetlands

Table 1 Vegetation communities of the Weld Range. Note this table only lists the seven main vegetation communities as recognised by Ecologia (2010); sub-communities are omitted.

Excavation Unit	Depth Below Surface (cm)	Laboratory Number	Material Dated	$\delta^{13}C$ Value	Uncalibrated Age (Years BP)	Calibrated Age (2σ) (Years cal. BP)
6	13	WK-32137	Charcoal	-22.5±0.2%	366±26	320–50
13c	36	WK-32138	Charcoal	-22.2±0.2%	3762±32	3980–4140
15	41	WK-32139	Charcoal	-22.6±0.2%	4866±36	5475–5600

Table 2 Radiocarbon dates from Weld-RS-0731. Dates were calibrated using OxCal 4.17 and results are conventional age or percent modern carbon (pMC) following Stuiver and Polach (1977) and based on Libby half-life of 5568 years with correction for isotropic fractionation applied.

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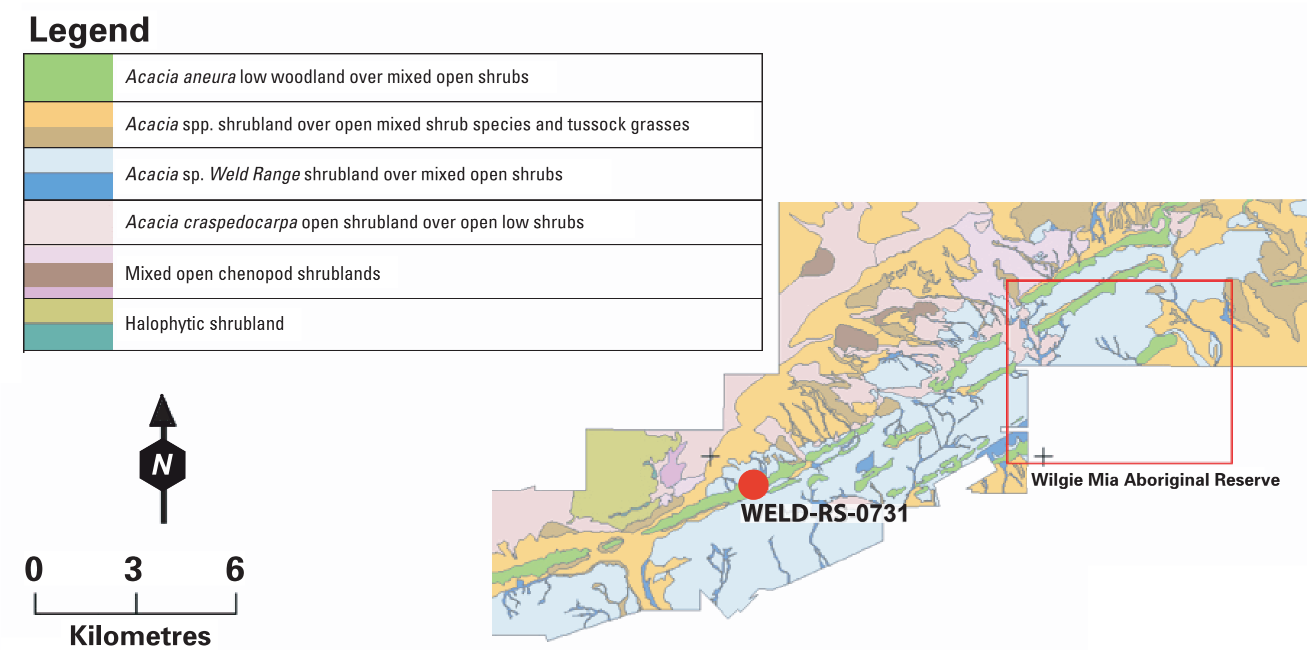


Figure 2 Vegetation communities map for Weld-RS-0731 (modified from Ecologia 2010).

In the Australian archaeological context, where short-term occupations of very mobile hunter-gatherers can be expected, it is not clear if scattered charcoals will always represent several fire events rather than just one. An additional research aim was hence to investigate if, and how, different time-frames of occupation are represented in the two anthracological assemblages of Weld-RS-0731, since they each represent different types of deposits.

Reference Collection Formation and Anatomical Database Use

Initially, the creation of a reference collection of local woody taxa was necessary, as no pre-existing reference collection or resources on local wood anatomy were available for the identification of charcoal from the Midwest region.

Research into the local vegetation led to the creation of a priority taxa list. Comparing the frequencies and diversities of taxa found in the archaeological charcoal assemblages to known communities not only assists in generating valid taxonomic identification, but also provides insights into the relationships and movements of people within the landscape over time. Consequently, the priority taxa list focused on species that would help characterise each of the different vegetation communities; species with contrasting ecological signatures; those with recorded ethnobotanical uses; and prominent taxa within the current landscape (as no data on past vegetation was available) (as per Dotte-Sarout 2010). Taxa with a maximum growth height of <3 m (such as grasses and small shrubs) were omitted from the investigation, as these were expected to be less likely to survive the charring process.

Wood (branch) samples were collected in the field, along with cuttings of each species' leaves, seeds and flowers. Photographs and locations using handheld GPS were taken for each tree/shrub sampled, and habitat descriptions made. Consultation with Traditional Owners and Indigenous ecological knowledge resources (e.g. Leyland 2002) yielded insights into the many ethnobotanical uses of the plants of the area. For example, we were informed that many *Grevillea* and *Eremophila* species

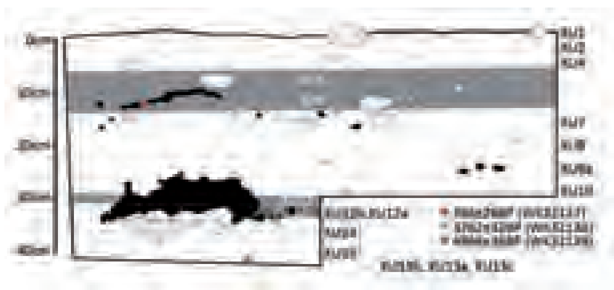
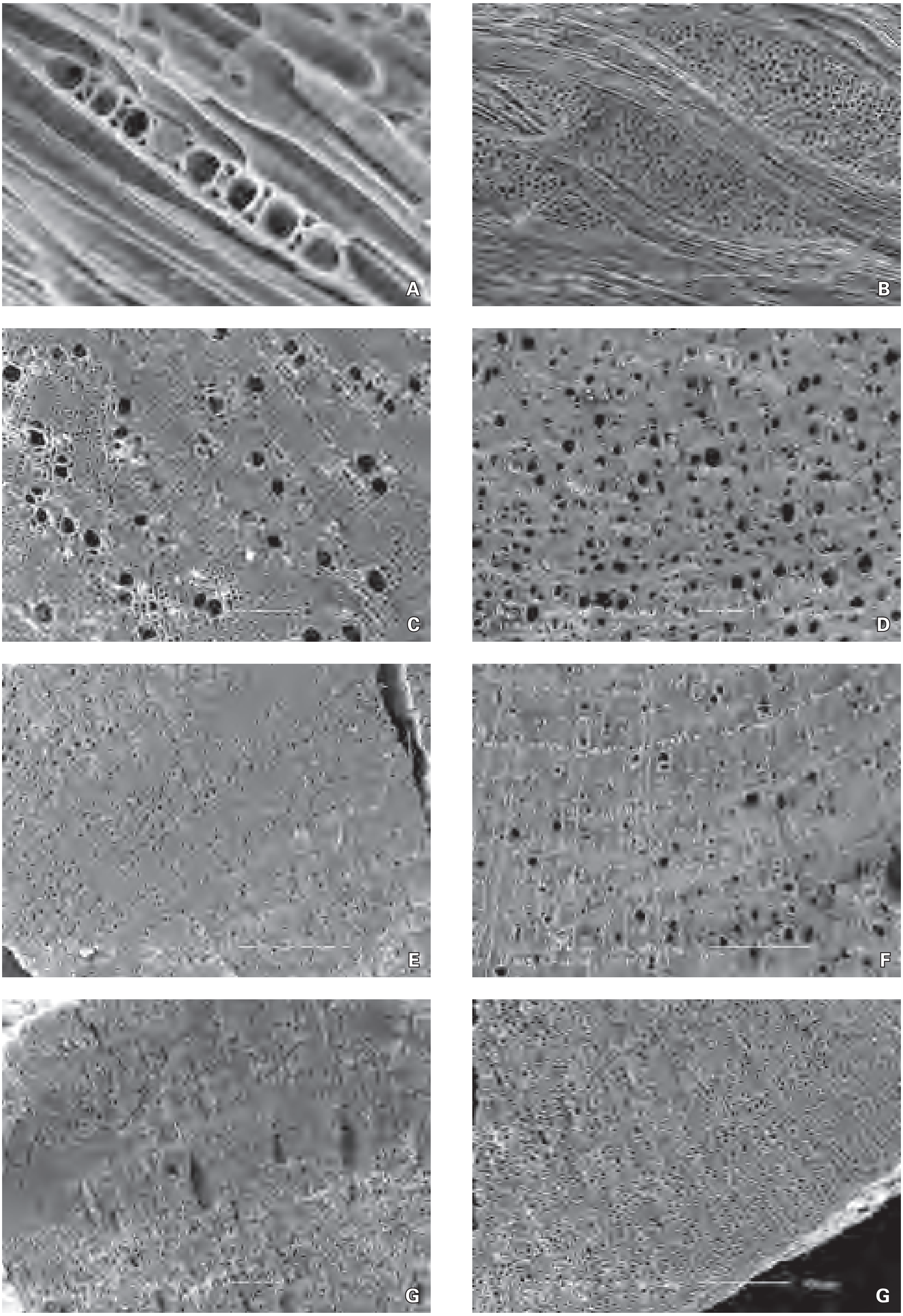


Figure 3 East section of the Weld-RS-0731 excavation. Key: charcoal = black; rocks = light grey; excavation units from which charcoal was sampled for this study are shaded in dark grey. Uncalibrated radiocarbon date sample locations are labelled.

produce woods prized for tool manufacture. Other taxa, such as the mulgas (*Acacia aneura* and *A. craspedocarpa*), yield a variety of foods, such as seeds, and house a variety of edible grubs and galls (Leyland 2002).

A total of 15 taxa were collected from the range and identified at the Kings Park Botanic Gardens and Parks Authority. All reference materials collected were angiosperms (or hardwood), thus reflecting the abundance of these plants in the modern landscape. The chosen taxa also represented the various vegetation communities recorded within the Range (Beard 1976; Curry et al. 1994; Ecologia 2010).

The woody samples were wrapped tightly in aluminium foil and placed in a pre-heated muffle furnace set to 400°C (see Asouti 2009; Pearsall 2000). Samples were charred until smoking ceased; this required an average burn time of 45 minutes. It should be noted that samples that required a longer, or secondary, burning appeared to be more susceptible to vitrification. The charred samples were then split by hand with aid of a scalpel to reveal the transverse (TS), tangential longitudinal (TLS) and radial longitudinal (TRS) anatomical planes. The absence, presence, form, size and arrangement of different anatomical elements were observed under reflected light using an Olympus BH2-UMA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microscope. Magnification ranged from 50x to 800x, each revealing the various characteristics of wood anatomical elements, including vessels, axial parenchyma, rays and fibres. Smaller features were observed using a scanning electron microscope (SEM), which was also used to take reference images of each specimen. The anatomical features of each taxon within the reference collection were recorded in a database, using a template developed by Dotte-Sarout (2010) (Figure 4 and Table 4). Terminology and features examined are based on Wheeler et al. (1989).

The method applied for archaeological identification was similar methodologically to that described above. Archaeological fragments were individually split by hand using a scalpel. Distinctive anatomical features were observed and entered in the database (Table 4) in order to launch queries for known taxa with similar features (for example, one can query the database for taxa with 'bordered vessel pitting'). The restricted list of taxa then allowed for a more detailed comparison of the anatomical features, using the database images and actual reference samples to achieve identification. Some species required the observation of very specific features, sometimes necessitating the use of high magnification and SEM imagery (Figure 4) (i.e. *Acacia* species can demonstrate a high degree of inter-species similarity, but details such as pore arrangement or vessel pit shapes can help identification at a species level [see Taylor 2012 for a detailed description of each of the *Acacia* species identified during this research]). Even where identifications could not be made to species level (e.g. those that were identified as either a Genus, Family, unidentified type or *confer*), samples were recorded using the same template, to ensure that each 'unidentified type' was not recorded more than once, thus affecting the later analysis of taxa diversity. Unidentified types were counted amongst the fragments analysed, as they provide information on the diversity of the deposit, while unidentifiable fragments (i.e. those with poor preservation which could not be identified) were noted, but not counted amongst the analysed specimens.

Quantification

The quantification of taxa in an anthracological assemblage is based on the counting of samples, rather than weight (Chabal 1992), which eliminates error margins that can arise when weighing small fragments (and especially after fragments have been broken for microscopic observation and identification). Weighing charcoal can also create a bias towards large fragments, 'resulting in a significant over-representation of some taxa in terms of weight' (Chabal 1992 as cited in Dotte-Sarout 2010:136).

Counting fragments has also been shown to provide an excellent representation of taxa frequency in charcoal assemblages due to the 'law of fragmentation', as first observed in a comparison of archaeological and experimental datasets (Chabal 1992; Thery-Parisot et al. 2010). Simply, the law states that, over time, the various taphonomic processes impacting an anthracological assemblage tend to reduce differential conservation related to intrinsic taxa characteristics and become more dependent on extrinsic conditions. Hence, in a given assemblage, rare taxa are typically represented by small fragments (i.e. 4 mm or less) and tend to be affected by under-fragmentation, while frequent taxa are typically represented by both small and large fragments and tend to experience over-fragmentation. Consequently, the under-fragmentation of rare taxa and over-fragmentation of frequent taxa leads to a reliable representation of the original burnt wood assemblage and, by extension of the PLE tenet, of the vegetation composition itself (Chabal et al. 1999). This is also why it is always recommended to collect and analyse charcoal fragments down to 2 or 3 mm, the practical limit of identification.

As noted earlier, anthracological practice recommends a minimum number of fragments be analysed to produce representative assemblages. For this study, the number of fragments analysed per assemblage was calculated using the species/area curve and Pareto Index. The species/area curve is an ecological tool which records the rate of appearance of new taxa within the assemblage against the number of fragments identified. The stabilisation of the curve indicates a sufficient representation of the taxonomic diversity as represented in the archaeological deposit (Chabal et al. 1999; Scheel-Ybert 2002) (Figures 5 and 7). Derived from an economic tool, the Pareto Index has been used by Chabal and others (Chabal 1992; Chabal et al. 1999; Scheel-Ybert 2002) to create anthracological indices based on experimental works for various regions around the globe. The Index measures the diversity of an assemblage by constructing relative frequencies as a function of taxa rank, which is expressed as a percentage. It is used to measure the representativeness of an anthracological assemblage in terms of vegetation composition (i.e. are the taxa rank and diversity appropriately represented?). The Index used as a reference in this project was 20:80, indicating that 20% of the species are represented by 80% of the samples in the charcoal assemblage. This figure has been observed for the Mediterranean and Middle Eastern arid zones (Chabal et al. 1999; Delhon 2006), while indices of 25:75 to 30:70 have been demonstrated to characterise tropical environments (Dotte-Sarout 2010; Scheel-Ybert 2002). Given the absence of direct anthracological reference for Australian vegetation, the 20:80 Pareto Index was considered the most appropriate for the study site.

Results

A total of 483 archaeological fragments were analysed (Table 3). Except for three unidentified taxa from the family Mimosaceae, all identifications made were to species or genus-confer species level (noted cf. sp. and characterising identification lacking one or two of the discriminate features for identification at the species level). Eighteen different anatomical types were recognised, including seven *Acacia* species, seven other *Acacia* types to which a cf. species identification was assigned, one *Santalum* taxon and three Mimosaceae taxa for which no further identification could be ascertained but which are likely to be *Acacia* species not present in the database (see Taylor 2012 for their descriptions). Only one-sixth of the various taxa present

Figure 4 (opposite) SEM photographs of reference collection and archaeological charcoals. (a) *Acacia tetragonophylla,* tangential longitudinal section: ray; (b) *Grevillea berryana*, tangential longitudinal section: ray; (c) *A. aneura,* transverse section: axial parenchyma scanty paratracheal; (d) *A. coolgardiensis,* transverse section: axial parenchyma paratracheal confluent; (e) *A. craspedocarpa,* transverse section: axial parenchyma paratracheal confluent; (f) *A. tetragonophylla,* transverse section: axial parenchyma paratracheal confluent; (g) *Psydrax latifolia,* transverse section reference collection sample; and (h) *P. latifolia* transverse section archaeological sample.

Articles

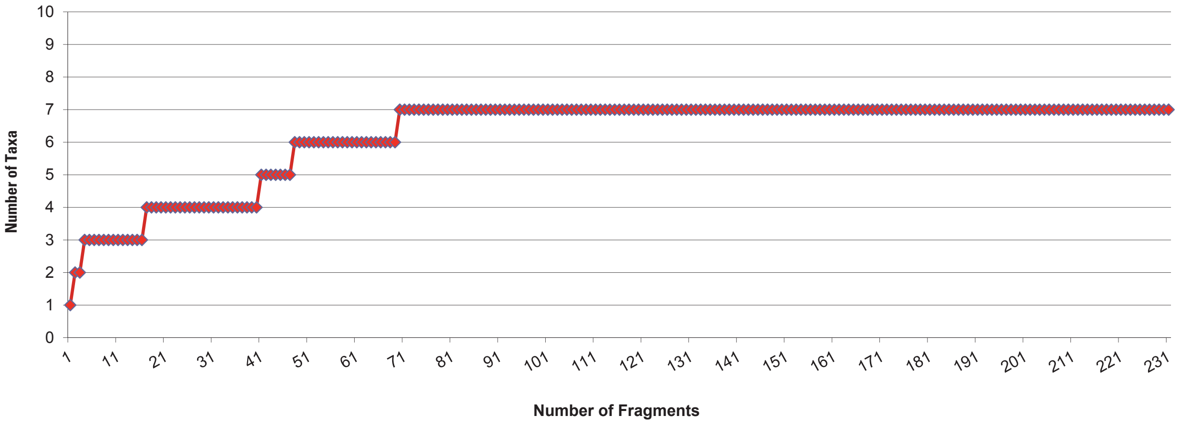

Figure 5 Species/area curve for upper hearth feature (XU5 and XU6).

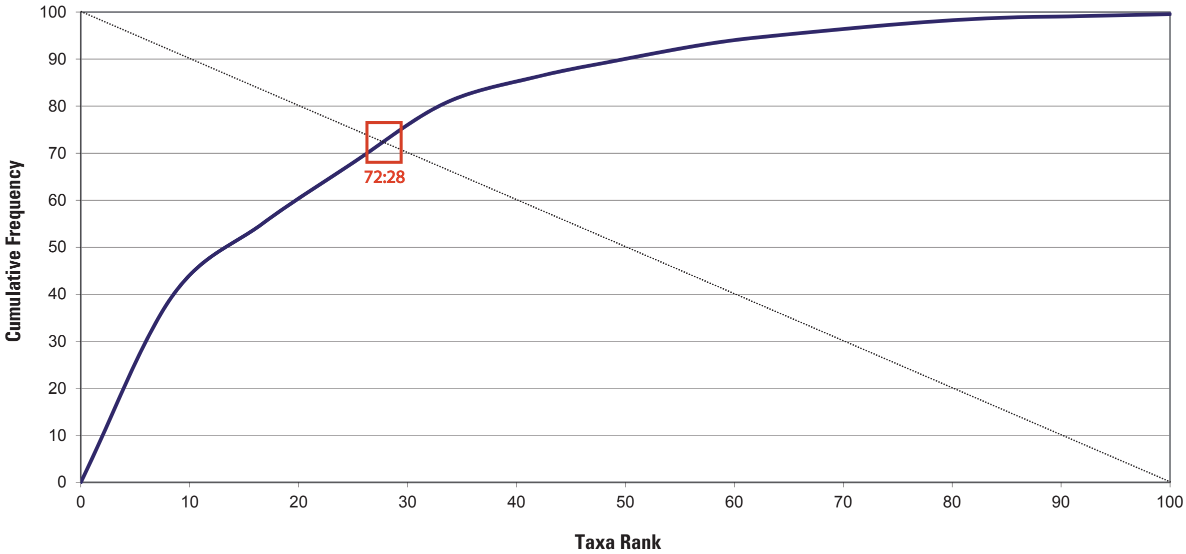

Figure 6 Gini-Lorenz curve for upper hearth feature (XU5 and XU6).

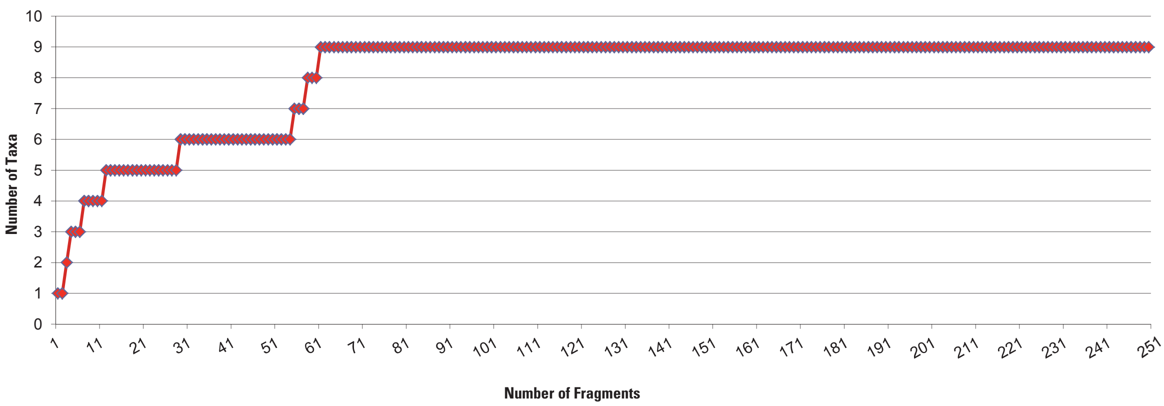

Figure 7 Species/area curve for lower hearth feature (XU11 and XU12c).

	UPPER FEATURE			LOWER FEATURE		
	Taxa Identified	Number Identified Fragments	Relative Frequency	Taxa Identified	Number Identified Fragments	Relative Frequency
Most Frequent → Least Frequent	*Acacia craspedocarpa*	92	39.83%	*Acacia craspedocarpa*	78	30.95%
	Acacia cf. *craspedocarpa*	36	15.58%	*Acacia* cf. *craspedocarpa*	23	9.13%
	Acacia aneura	31	13.42%	*Acacia aneura*	54	21.43%
	Acacia cf. *aneura*	29	12.55%	*Acacia* cf. *aneura*	37	14.68%
	Acacia cf. *tetragonophylla*	13	5.63%	*Psydrax latifolia*	11	4.37%
	Acacia tetragonophylla	9	3.90%	Unidentified MIMOSACEAE 3	10	3.97%
	Acacia cf. *coolgardiensis*	8	3.46%	*Acacia* cf. *tetragonophylla*	9	3.57%
	Acacia coolgardiensis	5	2.16%	Unidentified MIMOSACEAE 1	9	3.57%
	Acacia quadrimarginea	4	1.73%	*Acacia* cf. *grasbyi*	7	2.78%
	Acacia cf. *quadrimarginea*	2	0.87%	Unidentified MIMOSACEAE 2	6	2.38%
	Acacia cf. *grasbyi*	1	0.43%	*Acacia tetragonophylla*	5	1.98%
	Santalum cf. *spictum*	1	0.43%	*Acacia* cf. *pruinocarpa*	2	0.79%
				Acacia grasbyi	1	0.40%
	TOTAL	231	100.00%	TOTAL	252	100.00%

Table 3 Table of results of upper and lower hearth features.

in the assemblages were unidentified (with at least a Family level identification achieved, only 5% of analysed fragments were from the unidentifed Mimosaceae taxa and 60% of the fragments were identified to species level (Table 3).

The upper charcoal feature (XUs 5 and 6) revealed seven different taxa from 231 charcoal fragments. *Acacia* was the most frequent genus identified, with a total of six different species. The species/area curve stabilised after 71 fragments (Figure 5). An index of 72/28 was achieved, as demonstrated within the Gini-Lorenz curve (Figure 6). This index is slightly low, demonstrating a high diversity, and is likely due to the complexity of the deposit (both hearth and scattered charcoal).

The lower feature (XUs 11 and 12c) revealed a total of nine taxa from 252 charcoal fragments. *Acacia* was again the most frequent genus, with a total of five species identified, one less than the upper feature. *Psydrax latifolia* (bush plum) was not identified in the upper feature, but was common in the lower. Similarly, three unidentified Mimosaceae types were found in the lower feature, but further investigation is needed to identify the types, as well as to better understand this variant. The species/area curve stabilised after 61 fragments (Figure 7). The lower feature also revealed a Pareto Index of 72:28 (Figure 8). Hence, both our assemblages show low indices if the 20:80 Mediterranean Index is used as a reference. This might mean that the assemblages should have been even larger to achieve a better ecological representativeness in terms of taxa relative frequencies. Nevertheless, owing to the lack of references for anthracology in Australia, local indices need to be developed, as it remains possible that vegetation indices for the midwest are low in general.

Discussion

Three of the seven local modern vegetation communities and their predominant taxa appear to be represented in the examined archaeological assemblages from Weld-RS-0731. Overall, anthracological analysis reveals that the most common woody species in the range today are also those represented archaeologically, representing consistency over nearly 4000 years. Both the reference collection and the archaeological charcoals clearly reflect the *Acacia*-dominated vegetation of the region. Of the 483 archaeological fragments examined, 446 were *Acacia*, giving this genus a 92% representation within the archaeological assemblage (Table 3). The three most common taxa in both assemblages include *A. craspedocarpa* (hop mulga), *A. aneura* (mulga) and *A. tetragonophylla* (kurara). These taxa are known to produce a great variety of economic resources such as seeds, saps, grubs and galls (Leyland 2002).

The dominant species in the current landscape, *A. aneura*, is, however, not the most frequent in the Weld-RS-0731 assemblages, which is instead *A. craspedocarpa*. The three dominant *Acacia* species in the two assemblages are the most commonly associated and abundant taxa in the *A. craspedocarpa* open shrubland over open low shrubs and mixed open chenopod shrubland vegetation communities (after Ecologia 2010) (Table 1, Figure 9). These communities are associated with water habitats (low-lying, salt lakes, drainage lines and riparian areas) where *A. craspedocarpa* is the dominant species.

The results suggest that past occupants of Weld-RS-0731 favoured fuel collection near water resources, rather than amongst the *A. aneura* low woodland over the mixed open shrubs community directly around the site (Figure 9). The representation of water-associated communities strongly indicates that, either, (a) the arrangement of vegetation communities in the Range has changed dramatically or, more likely, (b) that past occupants were selective in their gathering localities. Similarly, charcoal analysis at Puritjarra revealed that occupants travelled some 2 km from the site to gather fuel species (Smith et al. 1995). The presence of important subsistence-associated taxa at both Puritjarra and the Weld Range during the late Pleistocene and early Holocene supports the universal law that fire fuel was gathered while undertaking other subsistence tasks, such as seed gathering, rather than as a separate and task-specific venture. The integration of firewood collection with daily subsistence activities is a widely recognised human behavioural pattern observed around the world, most frequently featuring firewood collection during daily trips between habitations and agricultural fields, or food gathering locations (e.g. Asouti et al. 2005; Dotte-Sarout 2010; Dufraisse 2008; Picornell et al. 2011).

TAXA	VESSEL					FIBRES		PARENCHYMA		RAYS		
	Porosity	Grouping	Arrangement	Intervessel Pit Sizes	Intervessel Pit Shapes	Wall Thickness	Septate	Axial Parenchyma Arrangement	Fusiform	Width	Height	Cellular Composition
Acacia aneura	diffuse-porous	clusters common (2 or 3)+	radial to diagonal pattern	minute	simple and bordered	medium	no	scanty paratracheal	no	uniseriate	3 to 8	upright/square
Acacia pruinocarpa	semi-ring porous	clusters common (2 or 3)	wide spread	small	bordered	very thin	no	paratracheal confluent	no	uniseriate	5 to 13	upright/square
Acacia grasbyi	semi-ring porous	clusters common (2 or 3)	tangential bands	medium	bordered	thick	yes	paratracheal confluent	yes	uniseriate	3 to 5	mixed
Acacia quadrimarginea	semi-ring porous	clusters common (2 or 3)	radial to diagonal pattern	changeable	simple	thick	yes	paratracheal confluent	no	uniseriate	3 to 5	upright/square
Acacia coolgardiensis	diffuse-porous	exclusively solitary/ 90% +	wide spread	changeable	bordered	thick	yes	paratracheal confluent	no	uniseriate	3 to 4	mixed
Acacia tetragonophylla	diffuse-porous	clusters common (2 or 3)	radial to diagonal pattern	small	simple and bordered	medium	yes	paratracheal confluent	yes	uniseriate	3 to 20	mixed
Acacia craspedocarpa	semi-ring porous	in radial clusters	tangential bands	changeable	bordered	medium	yes	paratracheal confluent	no	uniseriate	2 to 10 (~4)	mixed

Table 4 Reference samples' anatomical features. Note that this table includes only some of the features analysed. Highlighted cells indicate the three most common taxa recovered from the archaeological assemblages. Identification of *Acacia* samples to species level requires experience gained through the observation of several hundreds of fragments, and time spent observing all features through all sections for each specimen analysed. For details of how features are defined see Taylor (2012) or IAWA list of hardwood features (Wheeler et al. 1989).

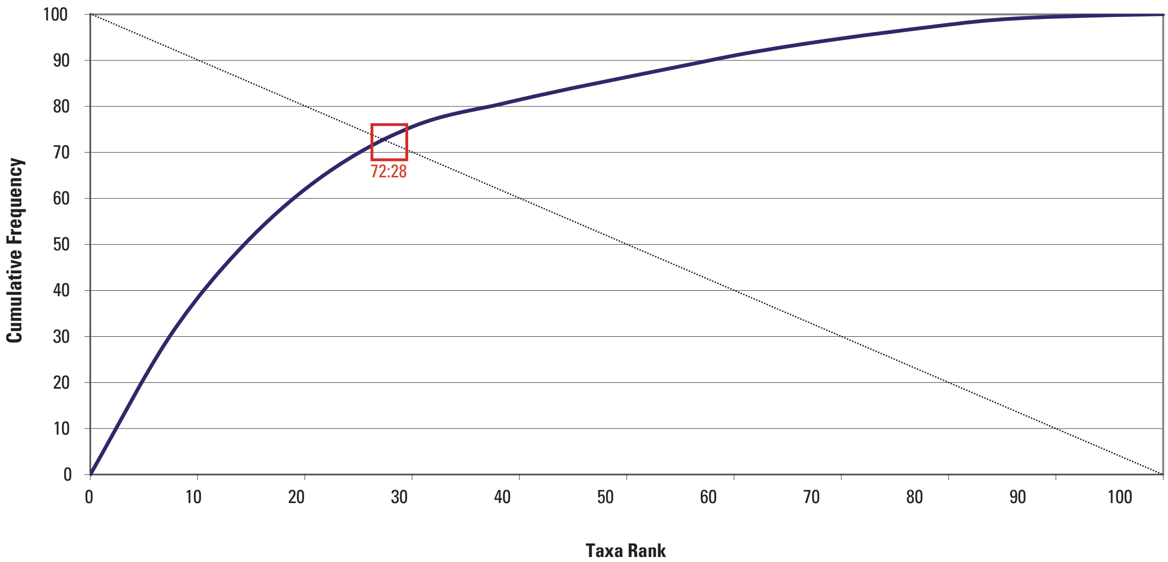

Figure 8 Gini-Lorenz curve for lower hearth feature.

Anthracological results from Weld-RS-0731 demonstrate that creek-line/water sources may have been the focus of daily activities—including food and fuel gathering—while habitation likely occurred in the elevated setting of the shelter. The nearest drainage line is found approximately 150 m downslope of the site, indicating that, based on current landforms, distances did not need to be large. This echoes the archaeological record of the local area. As noted above, variably dense and/or extensive artefact scatters occur adjacent to water sources and mark the focus of past human activities within a 2 km radius of Weld-RS-0731.

The presence of *Psydrax latifolia* exclusively in the lower feature (which is a secondary taxon of the local vegetation, often observed as an understorey taxon in association with *Acacia* woodlands in the study area) raises two interesting issues. Firstly, the presence of this shrub might indicate that it was collected for a specific use. The dense charcoal feature this assemblage represents could potentially have been a cooking pit similar to the one Smith et al. (1995:173) interpreted in the deposits at Puritjarra. Unfortunately, the Weld-RS-0731 test-pit was not wide enough at this depth to verify the feature's form or likely function. Secondly, its presence might indicate that it was used by people for fuel and is conserved in anthracological deposits contra frequent expectations. Its presence also demonstrates that examining scattered charcoal is essential for the palaeoenvironmental validity of anthracological assemblages. Indeed, the fragments from the upper feature represent both the dense hearth and scattered surrounding charcoal. In contrast, fragments collected from the lower hearth come from a dense feature, thus likely reflecting only the last few fire events. It is probable that the relatively high frequency of *P. latifolia* in the lower hearth assemblage is an over-representation, resulting from a single firewood collection and deposition event, rather than a genuine signature of this taxon's greater frequency across the ancient landscape. Comparison of the two Weld-RS-0731 anthracological assemblages confirms previous observations that assemblages of scattered charcoals from occupation levels contain relative frequency/proportions of taxa more representative of past vegetation. Moreover, even in an Australian context, *scattered* charcoals tend to represent several wood collection events, while charcoal *features* commonly reflect single anthropogenic events.

The PLE states that people collect firewood in relation to its availability in the surrounding landscape and thus in direct proportion to vegetation composition. The abundance of *A. aneura* and *A. craspedocarpa* in both Weld-RS-0731 assemblages indicates that occupants indeed used the dominant mulga species, which is known to be a long-burning fuel. If the site's occupants were collecting wood randomly, a wider diversity of species from the Range would be expected to be present in the assemblages. For example, *Eremophila* and *Grevillea* are amongst the most abundant taxa in the Range, but are completely absent from both anthracological assemblages. Species from both taxa are known to produce very light wood with poor fuel quality and, as noted earlier, these taxa are favoured by the Wajarii for wood carving. The presence of *P. latifolia* in the older assemblage demonstrates that the preservation of charcoal remains from small shrubs/light wood is possible. Hence, the absence of *Eremophila* and *Grevillea* from both Weld-RS-0731 assemblages represents an interesting 'pattern of avoidance' in firewood collection practice. This mixture of taxa-availability and avoidance of specific taxa (or habitats) is another frequently observed pattern (see Dotte-Sarout 2010; Picornell et al. 2011). The association of avoidance and PLE in wood gathering behaviours demonstrates how the management of natural resources is mostly the product of both environmental opportunity and socio-cultural choice. These results also exemplify how anthracological analyses harnessing valid and statistically robust assemblage and sampling protocols can lead to the identification of the different factors affecting fuel collection.

Conclusion

Anthracological analysis of two charcoal features from the Weld-RS-0731 rockshelter in the Weld Range shows that, although

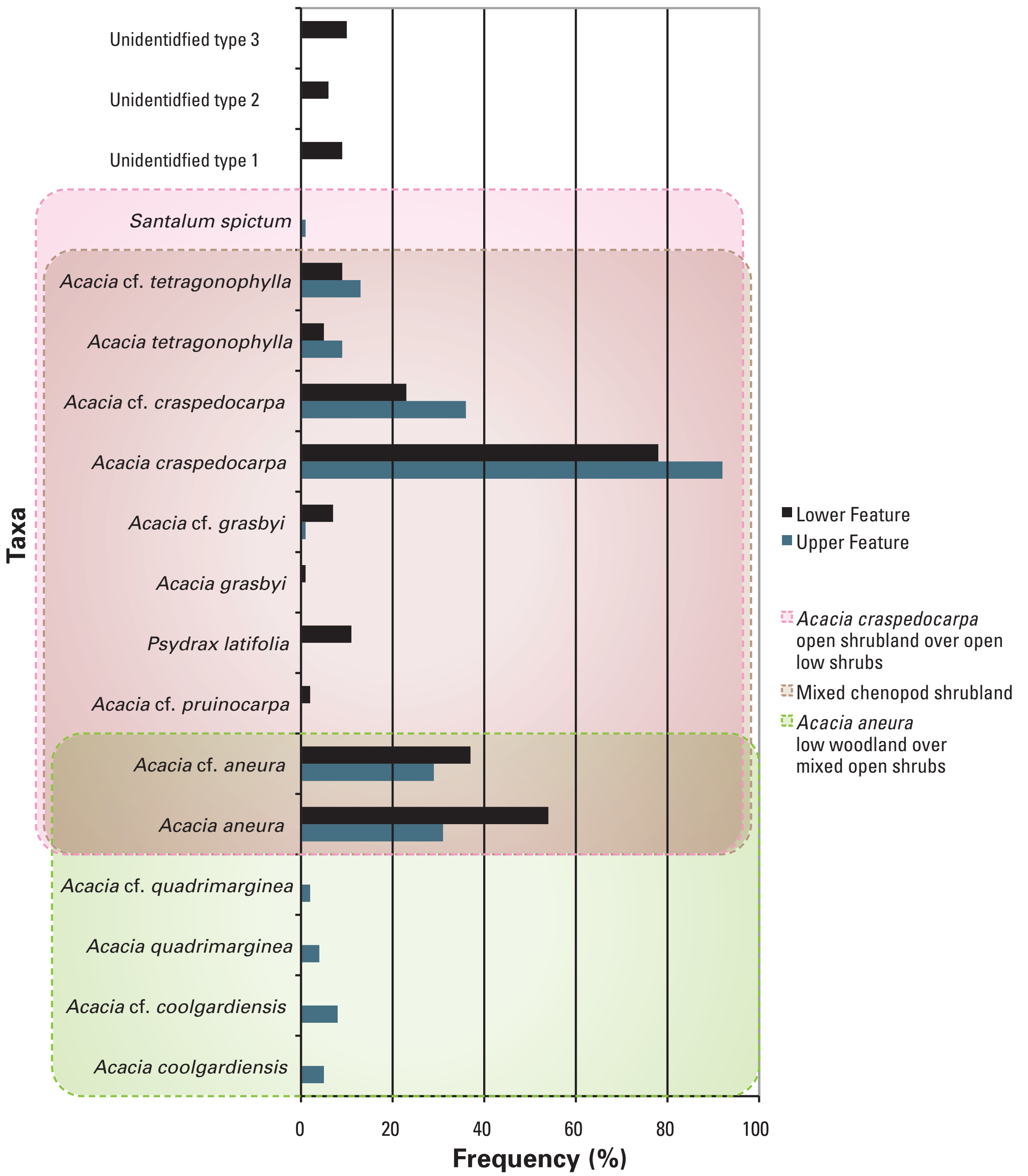

Figure 9 Taxa frequency and vegetation communities identified in the anthracological assemblages ('anthracological spectra'). Vegetation communities colour key: *Acacia craspedocarpa* open shrubland over open low shrubs = pink; Mixed chenopod shrubland (brown); and *A. aneura* low woodland over mixed open shrubs (green).

past occupants collected firewood in direct relation to taxa availability in the landscape, they exploited vegetation resources following specific strategies. Firstly, it appears that fuel wood was mainly collected amongst vegetation communities associated with drainage lines and water sources (i.e. *A. craspedocarpa* dominated), rather than within the more common *A. aneura* communities expected to be found directly around the rockshelter. Anthracological results converge with other archaeological data from the Range to demonstrate that water sources and drainage lines represented a focus of daily activities for the past occupants of the area. The most frequent taxa identified are also characterised as important food sources. Secondly, while it seems occupants collected fuel which required the least effort (i.e. taxa which were amongst the most common within the landscape and probably situated along daily routes for a range of subsistence activities, such as seed gathering), they were selective in their choice of species. Indeed, the analysis shows that, although people were using widespread *Acacia* species, they ignored other frequently occurring species, such as *Eremophila* spp. and *Grevillea* spp., that are known to produce poor fuel and/or are reserved for other uses (such as wood carving). Once the potential bias introduced by avoidance of taxa with poor fuel value has been considered, both assemblages have coherent taxa rank and taxonomic compositions and provide proportionally fair representations of the major vegetation communities of the Weld Range today.

This research represents a pilot attempt to apply the basic principles and methodologies of anthracology in Australia. It provides initial, direct evidence concerning both the management of fire fuels by Aboriginal inhabitants of the Midwest and palaeovegetation of the region during the late Holocene. The results show that, with sufficient training and access to appropriate reference material, as well as methodological rigour, detailed anthracological analysis on threshold samples from features found in small excavations is feasible. However, it also exemplifies: (a) the need to liaise with an anthracologist before and during fieldwork to plan adequate sampling; (b) the need to analyse large assemblages producing valid results; and (3) the current limits for Australian anthracology and the need to multiply test-applications in order to develop local references for methodology and interpretation of results. More importantly, we believe this study demonstrates how anthracology can provide both palaeoethnobotanical and palaeoenvironmental data that are pertinent to the overall understanding of an archaeological site, shedding light on general issues such as past occupants' mobility in the landscape.

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