Many words for fire: an etymological and micromorphological consideration of combustion features in Indigenous archaeological sites of Western Australia

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Abstract

The word 'fire' encompasses an enormous variety of human activities and has diverse cultural meanings. The word *hearth* not only has links with fire but also has a social focus both in its Latin origins and in Australian Indigenous languages, where hearth fire is primary to all other anthropogenic fires. The importance of fire to First Nations people is reflected in the rich vocabulary of associated words, from different hearth types and fuel to the different purposes of fire in relation to cooking, medicine, ritual or management of the environment. Likewise, the archaeological expression of hearths and other combustion features is equally complex and nuanced, and can be explored on a microscale using micromorphology. Here we highlight the complexity in both language and micromorphological expressions around a range of documented and less well documented combustion features, including examples from archaeological sites in Western Australia. Our purpose is to discourage the over-use of the generalised term 'hearth' to describe charcoal and ash-rich features, and encourage a more nuanced study of the burnt record in a cultural context.

Keywords: fire, hearth, micromorphology, language, Australia

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BACKGROUND

> '*The hearth fire defined the human world…*' (Pyne 1991, p. 91)

Australia is a continent that burns regularly and in which burned or blackened features are common within archaeological sites. Such features, with or without macroscopic charcoal, are often interpreted as deriving from hearths or the remains of campfires. Whereas the term 'hearth' generally refers to in situ and intact combustion features, less intact blackened, carbonised or ashy features cannot be assumed to be undisturbed or have a cultural origin, or even to be a result of burning (Mentzer 2014; McNiven *et al*. 2018). In the Scopus database the combination of the keywords 'hearth', 'Australia' and 'archaeology' return 23 results but replacing hearth with 'combustion feature' returns only two (Wood *et al*. 2016; Whitau *et al*. 2018) indicating a default interpretation of an in situ cultural hearth. However, there is significant fire-science literature that makes it clear that not all fire is the same (e.g. Pyne 1991; Bowman *et al*. 2011; Scott *et al*. 2014; Tulua 2015) and ethnographic and archaeological literature that similarly indicates great variability in the archaeological traces of hearths (Friesem 2018; Mallol *et al*. 2007, 2017; March *et al*. 2014; Alperson-Afil 2017). The latter are influenced by the function, form and size of the hearth and by the post-depositional processes (e.g. age, soil chemistry, bioturbation) that preserves them (Holdaway *et al*. 2017).

First Nations people in Australia use fire in many ways, and various words in Aboriginal and Torres Strait Islander languages correspondingly describe different types of fire, its behaviour and effects, and also relationships of people with it. In Noongar, the Aboriginal language of southern Western Australia, the word for fire *karl/kaarla* and is the same word for immediate family; similarly *karluk/karlup* means 'place of fire or hearth' (figurative) but also 'home or heart country' (Kelly 1998), a focus mirrored elsewhere around the country. Interestingly, terminology explaining fire as a social focus mirrors the Latin definition of 'focus' which literally means hearth or fireplace. In fact, Pyne (1991, p. 91) denoted the hearth fire as the 'original' of all other anthropogenic fires to the extent that 'without it human society was unthinkable'.

There is also language associated with different types of hearths, such as earth or ground (dug) ovens, which are known variously as *ilda* by Yura Yakarti people in the Flinders Ranges of South Australia (Tunbridge 1985), *kup murri/kup maurior* by Torres Strait Islander (Monaghan 2007; Mua 2018) [i] and also *yulh-tha* by some Cape York people (Alpher 1991), and as *mirnyongs* in eastern and south-eastern Australia (Chauncy 1878, p. 232; Fig. 1).

[i] See also https://indigenousx.com.au/prioritise-indigenous-knowledges-and-embed-a-western-science-perspective/

Earth ovens may be further distinguished by the different heat retaining elements used and may be differentiated again from rock-filled pit-hearths (Fanning & Holdaway 2001; Wallis *et al*. 2004; Rhodes *et al*. 2009) or surface fires. The Yindjibarndi people of the Pilbara accordingly have different words for a stone hearth *mirin* and a shallow pit fire *yuwarta* (Wordick 1982). More broadly, there is a distinction in language and purpose around fire and hearths.

Fire was not only used for cooking food (*dookerniny* in Noongar (Douglass 1996), *kampa* in Yindjibarndi (Wordick 1982)). Other purposes include warmth (including fires around the camp bed; Douglas 1988), for light (*nyurnmatjali;* Western Desert (Douglass 1988) and *lorrn;* Cape York (Alpher 1991)), hunting (e.g. Bird *et al*. 2008), signalling (e.g. Gould 1971, p. 20; Musharbash 2018), medicine (smoking; e.g. Kelly 1998; Musharbash 2018) and ceremony, including the peacemaking 'fire ceremony' (see Morton nd and references therein). There is also caring-for-country fire (e.g. Hallam 1975; Dortch 2005; Lloyd & Krasnostein 2006), with a similarly rich terminology as Hopper (2019, p. 8) outlined for Noongar:

> Country and various stages in the burning cycle are named firstly *bokyt*—covered in vegetation yet to be burnt—from *bwoka*, the kangaroo skin covering or cloak used for warmth in winter. Then there is *narrik* (dry country ready to burn), *narrow* (to burn slightly), *naariny, naarinj* (burning), *naaranany* (keep burning), *nappal* (burned ground over which fire has passed), and *kundyl* (young grass coming up after fire).

The complex human-fire–environmental relationship acknowledged through language can reveal much about purpose. How fire manifests archaeologically is equally complex and relates not only to the way fire was used but also to how it is preserved and recognised archaeologically (Goldberg *et al*. 2017).

One way to characterise and interpret combustion features in the archaeological record is through micromorphology—a technique that reveals indicators of fire such as char, ash, bone, organic residues and heat-altered sediment in context with sedimentary fabrics characteristics of depositional and environmental processes (Mallol *et al*. 2017; Mentzer 2017). Micromorphology has been used to discriminate surface fires from ground ovens (e.g. Aldeias *et al*. 2016; Haaland *et al*. 2017; Whitau *et al*. 2018), single or multiple hearth use (e.g. Meignen *et al*. 2007), and hearths from secondary ash dumps (e.g. Schiegl *et al*. 2003; Friesem *et al*. 2014). However, with few exceptions (Whitau *et al*. 2018), micromorphology is still largely underused in describing combustion features in Australia.

Focusing mainly on Western Australia, we explore some etymological and micromorphological differences in expression and purpose of combustion features, and in particular in situ hearths, drawing on a range of published and unpublished archaeological sites and language sources. We use Alperson-Alfil's (2017) definition of a hearth as 'an anthropogenic combustion area variable in structure, size, and depth that preserves the remains of burned materials'. It should be noted that two of the micromorphological examples of combustion features presented in this paper were obtained opportunistically from sites sampled during contractual work and one as part of a dedicated research study on Barrow Island off northwestern Australia (Fig. 1). The main purpose of our discussion, which follows others in the same vein (e.g. Aldeias *et al*. 2016; Aldeias 2017; Mentzer 2014), is to highlight the complexity around combustion features as observed in archaeological excavation, and discourage the indiscriminate and inaccurate use of the term hearth to describe these in Australian archaeological discourses. We hope to encourage more studies in Australia to apply geoarchaeological, experimental and ethnoarchaeological methodologies to the study of fire and pyrotechnology to enrich our understanding of the past.

COMBUSTION FEATURES AND THEIR MICROMORPHOLOGICAL CHARACTERISATION

There have been numerous studies on indigenous 'hearth' features in Australia. These are typically regional in aspect (e.g. Beveridge 1869; Wallis *et al*. 2004; Martin 2006; Holdaway *et al*. 2017), with those in and around the Murray Darling (Riverina) area drawing particular attention to mound ovens (Berryman & Frankel 1984; Williams 1985). Other studies explore methods for identifying hearths and their proxies (e.g. burnt bones, charcoal, ash) from geophysical (e.g. Ross *et al*. 2019), chemical (e.g. Singh *et al*. 1991), chronological (e.g. Walshe 2012; Fanning & Holdaway 2001), microscopic techniques (e.g. Whitau *et al*. 2018) and through archaeological experimentation (e.g. Campanelli *et al*. 2018). Other published literature relates to Indigenous language around fire and hearths (Evans 1992; Musharbash 2018). Here we describe different types of combustion features, not all of which can be described as hearths, and how both language and micromorphology might further aid understanding.

Indigenous earth ovens

Indigenous earth ovens—also described as ground ovens, pit oven, heat-retainer oven or hearth—essentially describe those that are dug into the ground, which in profile may intersect an earlier surface. Such ground ovens may be dug over and reformed many times so that intact pits and combustion features may not be common. These may be formed into 'oven mounds' or 'ash hills' (Pyne 1991, p. 89; Ross *et al*. 2019)—in areas with high rainfall and poorly drained soils such mounds may be further repurposed as camping areas or as foundations for huts (Williams 1985). Small mounds bearing fire residues could therefore signify an oven or the remains of a burnt down hut.

Citing Tunbridge (1985), Walsh (2012) described how earth ovens were made by burning wood in a dug hole to form 'coals' (i.e. biochar), to which the food is added and then sealed with hot ash and more 'coals'. Sometimes vegetation is also put into the hole and water poured over the coals to create a steaming effect before sealing.[ii] Rocks

[ii] A similar process, which also uses bark to cover the oven, is also described by the BarengiGadjin people in Victoria: see https://www.youtube.com/watch?v=m-hBCVrk4LQ

were occasionally added, but these had been described ethnohistorically as dangerous due to their 'propensity to explode and embed ... in someone's flesh' (Tunbridge 1985, p. 19). An early account of 'Aboriginal Ovens' by Peter Beveridge (1869) described how baked clay—earth nodules 'baked into the consistency of brick [*sic*.]'—is used if stones were not readily available (see also Martin 2011 and references therein). The hot clay is removed by a pair of 'aboriginal tongs [*sic*.]', after which the hole is carefully swept out, and then lined with damp grass into which the food (often meat) is placed. The oven is sealed with more damp grass and covered with hot clay and fine earth, but never ash. Once the meat is cooked, the covering is scraped off, and the residues (heat-altered clay, ashes, and earth) becomes the nucleus of subsequent earth ovens.

As implied from the term, a heat-retainer oven involves the use of heating elements, including lumps from termite nests (e.g. *Drepanotermes perniger*), baked earth (clay), calcrete nodules, stones, charcoal (a man-made product) or coals (a natural mineral; Coutts *et al*. 1979; Berryman & Frankel 1984). Each of these have different cultural terms. In the Yindjibarndi language of the Pilbara, *yawan* is the word for cooking stone (Wordick 1982). In Noongar, charcoal is *kop*, coals *bridal* and white ash *yoort*; and in the Yir-Yiront lexicon of Cape York, distinction is made between hot ashes *thum-nhaq* and cold ashes *thum-nhur* (Alpher 1991). Each of these elements may have different micromophological expression (Mentzer 2017). Villagran *et al*. (2019), for example, used micromorphology and micro-CT scanning methods to detect fragments of termite mounds in ash-rich sediments within a Holocene archaeological site in Brazil, as evidence of their possible use in earth ovens. A more recent study by Leierer *et al*. (2020) couples micromorphology with lipid biomarker analysis to help identify fuel sources and burning temperatures in a pit fire in a Middle Palaeolithic site in Spain.

In contrast to small, open fires, cooking in an earth oven occurs within a closed, or reducing atmosphere, often with steam as the main cooking agent (Willams 1985, p. 110). Hence deposits associated with earth ovens would tend to have a higher proportion of charcoal than ash. Temperatures reached during the cooking process in earth ovens are likely to be high (>500°C) and should be reflected at macro- and microscale in the surrounding earth (Gur-Arieh *et al*. 2013; Singh *et al*. 1991), as well as by the presence of heat-fractured rock or altered bone (e.g. Shipman *et al*. 1984; Table 1). Martin (2011), for example, used the common presence of fused silica particles and white (rather than grey) calcined bone to indicate heating temperatures of between 600°C and 900°C in one excavated mound oven. More empirical measures of temperature can be gained from use of Fourier Transform Infrared spectroscopy (FTIR and micro-FTIR) techniques (Ellingham *et al*. 2015) but these have yet to be applied more extensively in Australian archaeological contexts (e.g. Lowe *et al*. 2018). Other features of earth ovens include partially-combusted plant matter, as well as greater quantities of larger, solid charcoal (Fig. 1B) as a result of the low oxygen conditions, which may or may not be present (e.g. Martin 2011; Whitau *et al*. 2018).

Figure 1 shows a sequence of (shallow) dug combustion features, including one interpreted as an earth or ground oven, from the ancient site of Riwi in the southern Kimberley (Fig. 1) (Whitau *et al*. 2018; also Vannieuwenhuyse 2016). A sharp boundary and

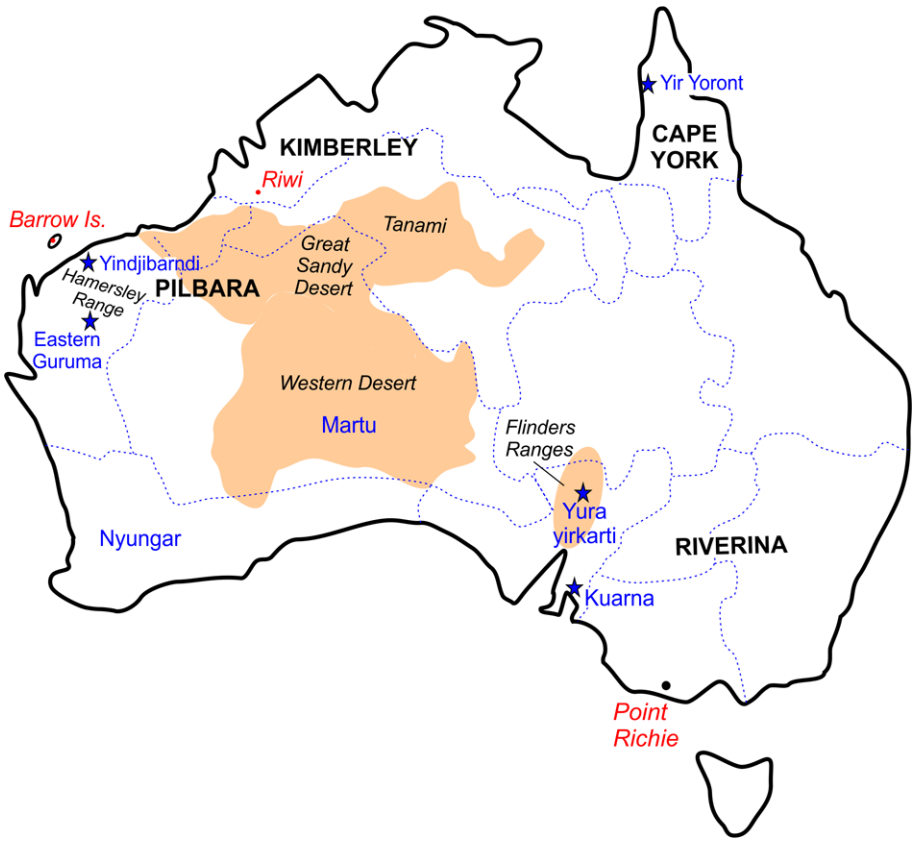

Figure 1. Simplified map showing regions (black text), approximate distribution of major language subgroups (blue dotted lines) and specific language groups (blue) and sites (red) mentioned in text

bedded, orientated particles at the base of the lowermost combustion feature (Fig. 2C) indices possible cutting into an older surface. Geogenic sediment within earth oven structures could be related to the covering of the fire with sediment, or may relate to preservation and whether the combustion feature is buried or not (Mallol *et al*. 2017). Ultimately more ethnographic and micromorphological studies are needed of traditional earth ovens to fully understand the variation and complexities around these.

Shallow pit and surface fires

Whilst they may have many purposes, the assumption—especially where wood has been completely combusted—is that surface fires are mainly expedient fires built for short-duration activities (e.g. Mallol *et al*. 2007; Friesem *et al*. 2017; Whitau *et al*. 2018). Unlike pit-hearths, hearths associated with surface fires are not dug into the substrate but merely sit atop it. They may, however, still entail a prepared surface and may preserve thin stratified lenses of ash and charcoal if left undisturbed and are buried quickly. A typical in situ hearth context shows burnt sediments below and sometimes above a well-defined (wood) ash layer (Mentzer 2014; Friesem *et al*. 2014; e.g. Fig. 3). These burnt sediments are sandwiched between unconsolidated surface sediments and an underlying ironstone unit, both into which burnt material has been mixed (Fig. 3).

Open fires are often used for a source of warmth and light, to warn off animals and as an important hub of social gathering (Douglass 1988; Pyne 1991; Dunbar 2014; Wiessner 2014), and for a variety of activities making use of fire energy (e.g. tool manufacture) and combusted materials (Pyne 1991; Friesem & Lavi 2017). Firelighting may utilise firesticks—*boorna karla/karlmoorl* in Noongar; *tjangi* in Martu; *koch* in Yir-Yiront lexicon— or *boya* stone (Douglass 1996), and may involve the use of grass, dried bark (*likarra*) or dung (*kuna*, Douglass 1988). Whilst it may be possible to distinguish stem, bark and grass or grass phytoliths, or similarly dung or spherulitic remains of dung (e.g. Vannieuwenhuyse 2016) in micromorphological thin section, it may be harder to determine whether these derive from natural or cultural processes.

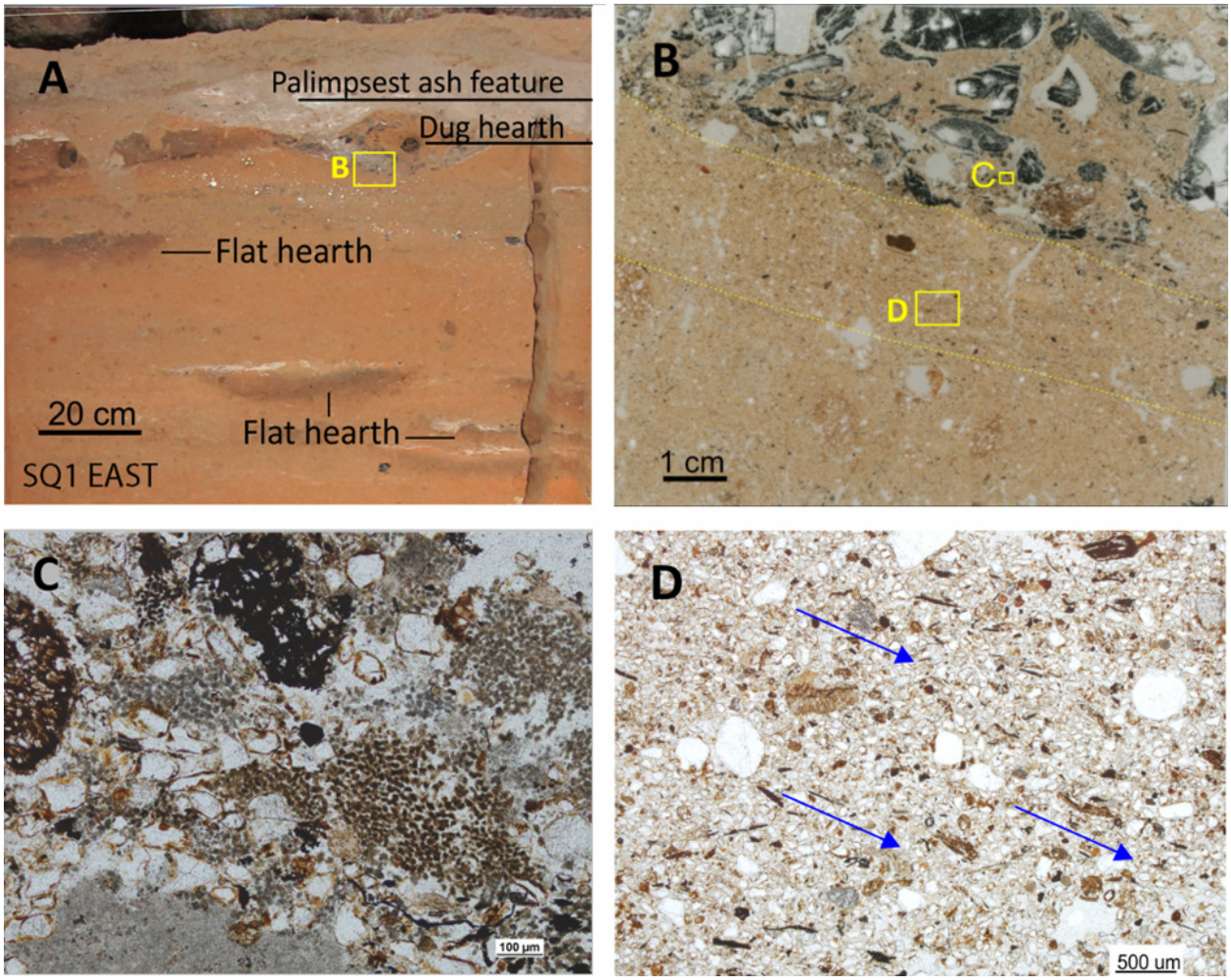

Figure 2. **A**. Field photograph showing a dug combustion feature overlying surface fires (flat hearths) in an excavation profile from Riwi in the Kimberley. **B**. The sharp basal transition of a dug hearth or earth oven within thin section R507 from this profile. Photomicrographs (plane-polarized light) from thin sections show: **C**. mixed charcoal fragments, ashes and geogenic sands, and **D**. bedded, orientated (direction indicated by blue arrows), organic particles below the combustion feature that could indicate digging. (Image modified from Whitau *et al*. 2018, fig. 8; Photomicrographs provided by Dorcas Vannieuwenhuyse).

Cooking (*dookerniny* in Noongar, *kampa* in Yindjibarndi) with surface fires (flat hearths) or dug hearths (pit hearths) may involve direct roasting over hot charcoals (*karl*, e.g. snakes, small mammals, insects), baking in the ashes (*karl-teerdup*, e.g. snakes, frogs, fish, dampers) or use of heat-retainers and hence may be expected to cover a broad range of temperatures. Food (e.g. fish, nuts) was sometimes wrapped in mud or soft bark before being covered in hot ashes (e.g. Meaghar 1975; Dilkes-Hall 2014), the remnants of which may be preserved at the microscale. Meagher (1975) describes the cooking of waterfowl in this way; when the baked mud was cracked open the feathers came away in the mud leaving the body clean. Microscopic evidence of feather barbules—probably from duck—have been found on Australian stone tools (Smith *et al*. 2015; see also Robertson 2002) hence potential exists for micromorphological evidence of bird feathers to also preserve. Again consideration needs to be given to a possible natural origin of faunal remains, such as from degradation of omnivorous coprolites that may contain feathers, tiny bone fragments, hairs, scales and insect fragments (e.g. Ward *et al*. 2019).

Another purpose of surface fires is for steaming or smoking. Smoke (*karl boyi* in Noongar, *yulyurdu* in the Tanami region) and the making of smoke (*kampa-purrkunku* in Yinjibarndi) is important in ceremonial and medicinal practices—to cleanse the spirit, including smoking of babies after childbirth ('baby cooking') [iii], to prevent the spirits of Old People from following a visitor to a place home, or for young boys after initiation (Richmond 1993; Scherjon *et al*. 2015; Musharbash 2018). Smoke is also used for therapeutic inhalation. The leaves of *Eremophila longifolia* (Berrigan emu bush), for example, is particularly favoured for smoking purposes as it produces a smoke with significant antimicrobial effects (Richmond 1993; Sadgrove *et al*. 2016). One variation thereof involves the creation of a bed of thick leaves over very hot stones, on which the patient was laid and then buried in warm sand up to the neck for several hours (Sadgrove & Jones 2016). To create smoke, leaves rather than tree wood is used, and this distinction may be visible from microscopic plant residues.

Figure 3 shows the remains of a surface fire as represented in a stratigraphic section, with baked sediment below (but not above), ash and charcoal deposits. The presence of ash particles in an anatomic connection (Fig. 3A) indicates the fire was in situ, and that such structures were not used repeatedly (Friesem *et al*. 2014; Mentzer 2014; Whitau *et al*. 2018). The hearth and surrounding sediment contain abundant (~20%) carbonised and degraded (but unidentified) plant

[iii] See also Central Australian Aboriginal Media Association Productions (2001) https://www.nfsa.gov.au/collection/curated/smoking-baby-muluru

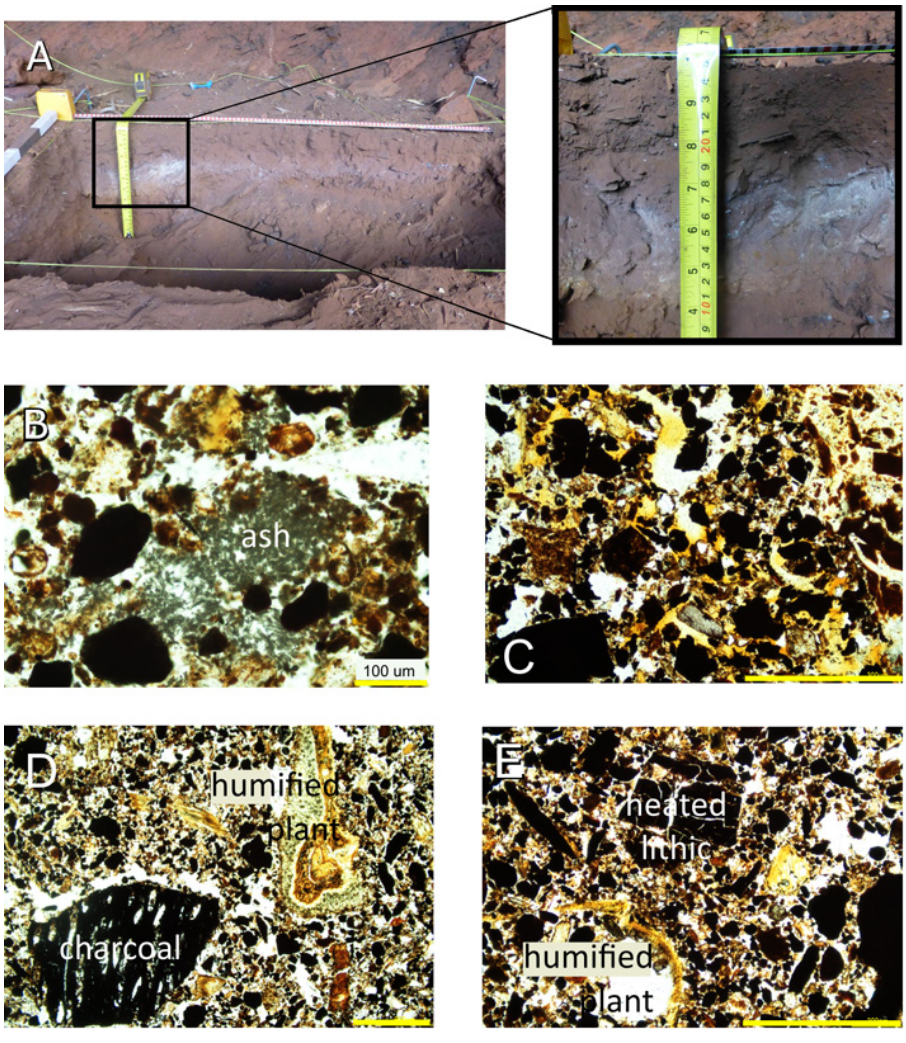

Figure 3. **A**. Field photograph showing a typical in situ hearth from a shallow excavation profile in the eastern Pilbara, with the remains of one or more burning events represented by charcoal and ashes overlying baked sediment. Photomicrographs of thin sections from this profile show: **B**. rhombic ash in anatomic connection and possible resin; **C**. possible resin (yellow stain); **D**. humified plant material and charcoal fragments; and **E**. fire-cracked rock with ferrugenous matrix. All photomicrographs are displayed in plane-polarized light and yellow scale bars are 1 mm unless marked otherwise. (images by IAKW).

material, including root, stem and leaf tissue from which resin appears to have been exuded (Fig. 3C). The inferred presence of resin in the deposit may derive from a highly volatile plant (e.g. spinifex) that was used as a firelighter, or the fire may have had a medicinal or other purpose. Although there are some burnt bone fragments, the predominance of plant material and small size of the hearth implies cooking was not its main purpose. Walters (1988) has noted that, in some instances at least, fires of First Nations people are kept clean and bone and

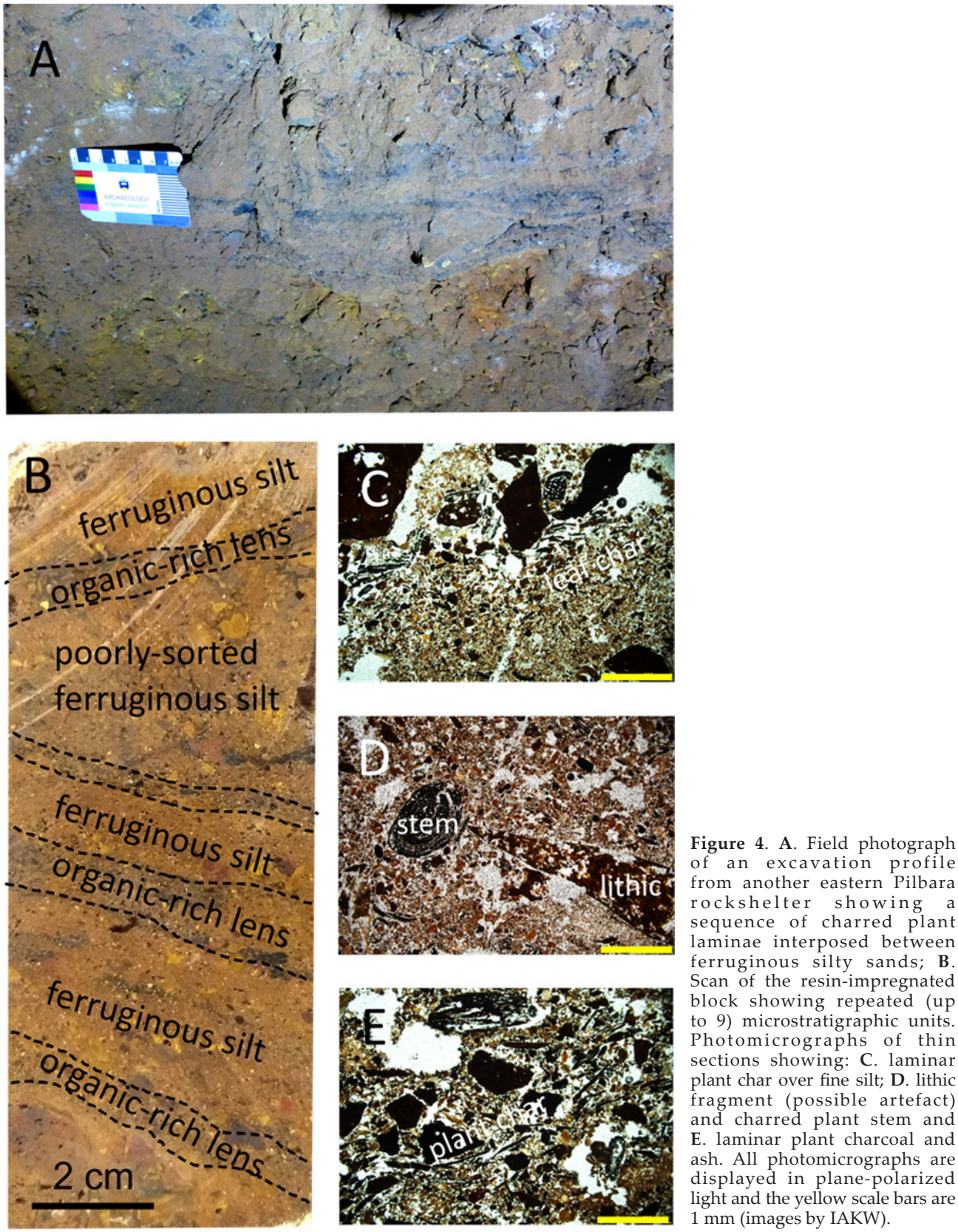

Figure 4. **A**. Field photograph of an excavation profile from another eastern Pilbara rockshelter showing a sequence of charred plant laminae interposed between ferruginous silty sands; **B**. Scan of the resin-impregnated block showing repeated (up to 9) microstratigraphic units. Photomicrographs of thin sections showing: **C**. laminar plant char over fine silt; **D**. lithic fragment (possible artefact) and charred plant stem and **E**. laminar plant charcoal and ash. All photomicrographs are displayed in plane-polarized light and the yellow scale bars are 1 mm (images by IAKW).

Table 1. Typology of combustion features (modified from Homsey & Capo 2006; Mentzer 2014; Goldberg *et al*. 2017; Whitau *et al*. 2017).

Combustion type	Archaeological expression		Taphonomy	Possible function and associated language
	Macro-	Micro-		
Earth/rock oven (ilda [i], kupmurri [ii], mirrnyong [iii], yulh-tha [iv])	• Intrude (prepared) surfaces • Basin profile • Charcoal-stained rocks (rock oven)	• High temp. burning ~500–900°C • Burned earth clasts • Thermally-altered rock • High geogenic content • Burned micro-artefacts (e.g. stone tools) • Partially-combusted organic matter	• Ovens often swept and reused and unless sealed, fire residues may have been removed. • Low post-depositional alteration (unless exposed)	• Cooking/steaming (dookerniny [v]; warukurrkaltj [vi]) • Lithic treatment
Surface hearth	• Prepared surface • Shallow profile (not dug in) • May be rock-lined	• Charcoal-rich or ash-rich (may preserve thin alternating layers of ash and charcoal) • Partially-combusted organic matter • Calcitic cellular pseudomorphs • Broad range of temperatures • (~200–500°C)	• Shallow, hence high post-depositional alteration	• Smoking/fumigation (puyu [vi]) • Quick cooking, e.g. opening shellfish • Light (nyurnmatjali [vi] • Warmth (yakunpa) [vi] • Social hub
Shallow pit hearth (karlup [v], yuwarta [vii])	• Prepared surface • May be rock-lined • Lens-shape profile	• Distinctive layers (from bottom to top) including altered/rubified soil substrate, charred remains and charcoal, ash layer • Articulated ash aggregates • May contain thermally altered rock • Moderate temp. burning ~200–600°C	• Shallow, hence high post-depositional alteration	• Cooking (dookerniny) including roasting, broiling, hot ash (thum-nhaq) [iv] • Light (nyurnmatjalivilorrn [iv]) • Warmth • Social hub
Tree hollow hearth	• Prepared area • Burning mainly internal (minimal external) • May be clay-lined (insulated)	• Charcoal-rich • Low geogenic component • May contain heated clay fragments • May contain evidence of termite activity	• Tree-cavity may be natural (e.g. termite, decay) or cultural (created with use of fire) • Area around tree hollow cleared of leaf litter • Sometimes lined by clay	• Cooking, inc. smoking (karlboy [iv], yulyurdu [vi]) • Social hub • (Shelter)
Maintenance (swept combustion feature)	• Heteregenous units	• Multiple microfacies • Splintered, fragmented charcoal and bone • Burned microartefacts	• Mixing evident from disturbed ash particles	• Discard
Secondary ash dump	• Relatively thick units • Lens/dome like shape	• Mixed deposit • Chaotic microstructure • Charcoal or ash-rich • Partially-burnt material • Low geogenic content • High porosity • Slight orientation of charcoal grains	• May be reworked or bioturbated	• Cleaning by-product

Language key: [i] South Australia (Tunbridge 1985); [ii] eastern and south-eastern Australia (Chauncy 1878), [iii] Torres Strait Islander and some Cape York people (Monaghan 2007); [iv] Yir-Yiront, Cape York (Alpher 1991); [v] South West Australia (Douglass 1996); [vi] Western Desert (Douglass 1988), [vii] Yinjibarndi, Pilbara (Wordick 1982).

rubbish are not discarded into the fires. Yet anecdotal evidence suggests that bone, especially fish bones, may be discarded into fires to avoid accidentally stepping on them (Lynley Wallis pers. comm. 2021). As such, absence of bone *per se* cannot be indicative of purpose.

Another interesting example of a site featuring combustion features rich in plant material is shown in Figure 4. Excavation of this eastern Pilbara rockshelter site revealed a series of relatively thin (< 2 cm) layered black, organic-rich units (approx. 30 cm across) interspersed with otherwise relatively homogenised iron-rich, silty sediment. In thin section some dark units have sharp boundaries, possibly indicative of surface preparation or alternatively a natural erosive event. This sequence shows repeated intact units of burnt, predominantly monocotyledon, plant material and minor ash (Figs 4C–F) that may be due to burning of bedding/floor matting, smoking to repel insects, or some other repeated activity. The stacked nature of the combustion structures imply a long hiatus between firelighting events (Mallol *et al*. 2013). Archaeological deposits generally also contain bedded unburnt vegetal tissue, which may evince human behaviour associated with combustion features (e.g. matting, wrapping for food items) or they may be naturally deposited (e.g. wind-blown leaves; Miller *et al*. 2010; Ismail-Meyer 2017).

Clearly the type of wood used in fire is an important part of identifying purpose, as different wood species will burn hotter and cleaner (e.g. Acacias), create more smoke for medicinal (e.g. *Eremophila*, *Callitris*, *Geijera*) or as an insect repellent (e.g. *Santalum* sp.; e.g. Specht 1958; Bindon & Peile 1986; Kamminga 1988; Sadgrove & Jones 2016; Sadgrove *et al*. 2016). These species usually have region-specific names that reflect local knowledge of plant use; a report by Ecoscape (2018) for example, lists Eastern Guruma (eastern Pilbara) names for plants including *wintamarra* for mulga (*Acacia aneura*), *nhirti* for emu bush (*Eremophila cuneifoli*) and *putaty* for sandalwood (*Santalum spicatum*). Some of these listed plants were identified for fire making, including kapok (*Aerva javanica*), kerosene grass (*Aristida contorta*) and camel bush or *kalyartu* (*Trichodesma zeylanicum*).

In Noongar country, resin such as that from the *Xanthorrhoea* (balga grass tree) was used to start fires using a balga stick (*mirliny*). In this region particular rocks, such as white quartz (*bilying*), were also used for firemaking (Douglas 1996), hence identification of rock types as well as plant species may also be relevant to understanding past fire use. Obviously fire studies can benefit from multiple approaches including micromorphology, anthracology (or other plant identification methods e.g. Whitau *et al*. 2018), ethnography and language.

Maintenance and secondary ash dump (rake-out) features

The repeated or multipurpose nature of anthropogenic fire use involves some level of management, including from the extinguishing of the fire (*warrugalgu* in Ngarluma (coastal Pilbara)) to the raking out of hearths, sweeping and dumping of debris elsewhere (O'Connell 1987; Fisher & Strickland 1989; Goldberg 2003; Friesem & Lavi 2017; Friesem *et al*. 2017). The micromorphological expression of a burning palimpsest will vary depending on the original nature(s) and purpose(s) of the fire(s) and the type(s) of maintenance practices (Friesem *et al*. 2017; Mallol *et al*. 2013; Miller *et al*. 2010) as well as any post-depositional trampling or reworking. Similarly, rake-out features and secondary ash dumps will display great variability although the accumulated material is likely to be highly heterogeneous and showing a chaotic structure (i.e., no preferred orientation; Table 1). It has been suggested that some earth mounds began as places to dump cooking refuse (Williams 1985, p. 304). More important is the complete lack of baked substrate that would otherwise indicate in situ burning (Schiegl *et al*. 2003; Friesem *et al*. 2014; cf. Mentzer 2014). The importance of differentiating rake-out features from in situ hearths is to highlight differential use of space in and around archaeological sites (Friesem & Lavi 2017, 2019) and one of major advantages of a micromorphological approach to assessing this is that small objects are more likely to remain in primary context (Meignen *et al*. 2007).

Figure 5 shows an example of a possible rake-out feature from a large coastal cave on Barrow Island, off the Pilbara coast (Fig. 1). An excavation against one of the walls near the front entrance exposed a 50 cm-deep highly mixed deposit (Fig. 5B) with significant post-depositional alteration. Micromorphological analysis of the deposits revealed a mix of charcoal (Fig. 5B), burnt and unburnt teeth and bone (Fig. 5D), shell (Fig. 5E), patches of ash (Fig. 5F) and fine silts. Whereas these secondary deposits were not particularly notable in themselves beyond the variety of debris they contained, they were of interest because they provided the best association for any kind of combustion feature, which has yet to be unearthed at the site. This rake-out deposit is close to the entrance and within the immediate area of occupation rather than farther back in the cave (cf. Schiegl *et al*. 2003). This likely increased the reworking of the deposit by burrowing fauna or by humans moving in and out of the cave, although there was no obvious trampled material observed in the thin section.

Other hearth types

To date there do not seem to have been any micromorphological studies of shell middens or shell midden hearths in Australia, although there is growing literature on this elsewhere (e.g. Aldeias *et al*. 2019; Villagran 2019). The term 'midden' is of Middle English derivation (from early Scandinavian; Danish: mødding, Swedish regional: mödding) according to the *Oxford English Dictionary* (3rd edition, 2003) and there may have been a comparable word or phrase used by First Nations people for a midden-hearth. There have been many studies in Australia relating to cooking shellfish, most notably that of Meehan (1982) that may aid future micromorphological studies. The shellfish cooking fires described by Meehan (1982) were mostly surface fires and less commonly using an 'oven' made of old shells and charcoal. The fire-related traces created by cooking shellfish range from thin to very 'ample' deposits of ash and charcoal, the latter sometimes accompanied by shells that had been used as 'heating plates' (Parkinton *et al*. 2009, p. 110).

Another poorly documented type of combustion feature are tree hollow hearths (Pyne 1991; Builth 2014),

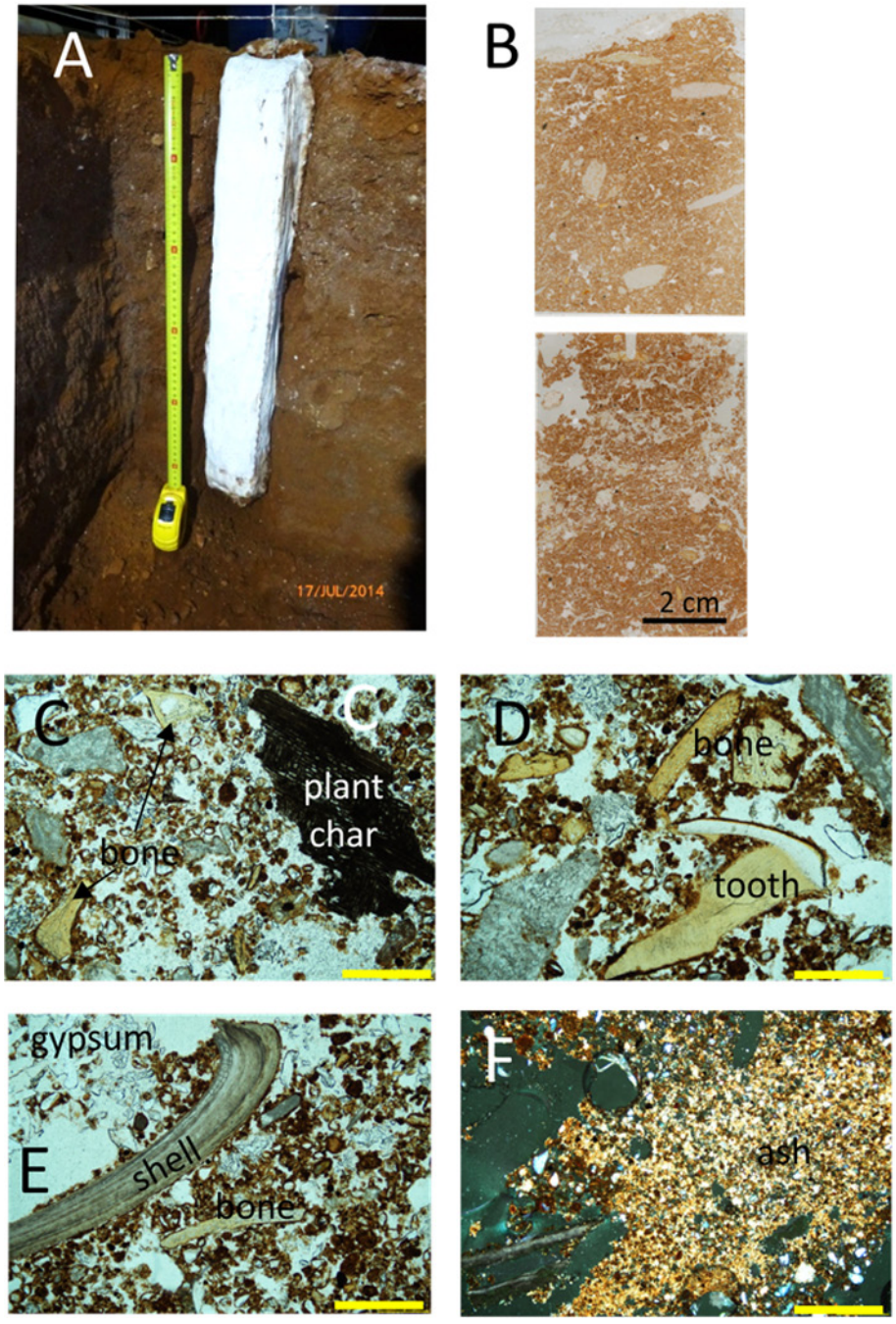

Figure 5. **A**. Field photograph showing resin profile sampling of a probable dump site, positioned against a rockshelter wall in a coastal cave on Barrow Island; **B**. Thin sections showing a largely homogenous sediment profile. Photomicrographs (plane-polarized light, unless otherwise stated) from thin sections within this profile show: **C**. plant/charcoal and bone (b) fragments in a matrix of limestone and fine clay; **D**. tooth and bone (b) fragments; **E**. shell and bone (b) fragments with gypsum (g) in voids; and **F**. concentrated area of micritic ash (cross-polarized light). Yellow scale bars are 1 cm. (images by IAKW).

which use natural hollows at the bases of trees or fallen trunks as ovens, smoking chambers or fire depots. Such features are more common on landforms that could otherwise not be dug into and/or where climatic conditions made it very difficult to find any shelter to cook staple foods—and where such landscapes had large trees. Larger hollows could even be used for shelter (Pyne 1991), and thus might have hearths built within them. Evidence in support of cultural burning within natural tree hollows tends to manifest as burning on only one side of the tree rather than around the whole circumference as in a natural bush fire. Clay may also have been used to line the interior hollow of the tree, thereby insulating them (Pyne 1991, p. 90). Although not documented, the use of hollowed trees as a protected space for smoking, fires or shelter may also extend to the wet south-west region of Western Australia where karri forests are endemic (Heather Builth pers. comm. 2021). Separated from the immediate substrate, such hearths might be expected to contain less geogenic sediment and more charcoal, with micromorphological evidence of bone or food residues and heated clay if used.

An example of an unusual hearth is a Kuarna 'burial hearth' documented by Owen & Pate (2014) in which 'hearths' (not described) were positioned over the hands of an individual as if to 'bind' them to the grave. A series of hearths (again not described) extending beyond the burial were interpreted as part of a 'sorry camp' connected with burial customs and the mourning period.

Further insight on these hearth types might be gained from micromorphological analysis and from the language used to describe them.

NATURAL VERSUS CULTURAL COMBUSTION FEATURES

Fire is a common element of the Australian environment even without humans, and natural fire events can result in deposits with similar characteristics to those formed through anthropogenic burning. An example of the importance of identifying anthropogenic hearth fire is particularly apparent at Moyjil (Point Ritchie) in Victoria, which McNiven *et al*. (2018) controversially postulated to date to the Last Interglacial. McNiven *et al*. (2018) identified the hearth as a concentrated area of charcoal and darkened sediment, and what appeared to be burnt sediments and rocks. Discriminating criteria were used to distinguish this as a cultural hearth from a naturally burnt feature (McNiven *et al*. 2018, table 3) but micromorphological analysis is still pending. Potential also exists to explore differences in residues from bushfire and hearth fires using microanalytical techniques, including signatures of heating on soil, wood charcoal and bone of native fauna (Berna *et al*. 2007; Weiner 2012; Ellingham *et al*. 2015). In general, the presence of rubified sediment or fire-cracked rock, charcoal or articulated ash lenses can all be used to identify intact combustion structures or hearths but none are unequivocal indictors. The presence of cultural material such as bone fragments of economic fauna, multiple charcoal taxa, ochre or exotic stone fragments, would support an interpretation of human activity (Barbetti 1986).

While work towards differentiating cultural and natural fire signatures in the sedimentary record is ongoing and beyond the scope of this study, useful insights may be gained from ethnography and language around cultural burning in order to inform future micromorphological studies. Foremost is that the vocabularies of First Nations people contain many words for fire whereas distinction is made between hearth fires and bushfire (Pyne 1991, p. 91). This is exemplified in semantic networks (e.g. Fig. 6), which show links between words associated with fire, camp and country. Distinction is made between bushfire, grassfire, fire, firewood, firestick, ash, charcoal, etc. with some words showing polysemy and common cognate sets. These cognate sets link languages with their geographic location and genetic affiliations, so that words can be used to generate maps relating not only to given meaning pairs but also human-behavioural processes relating to fire and country.

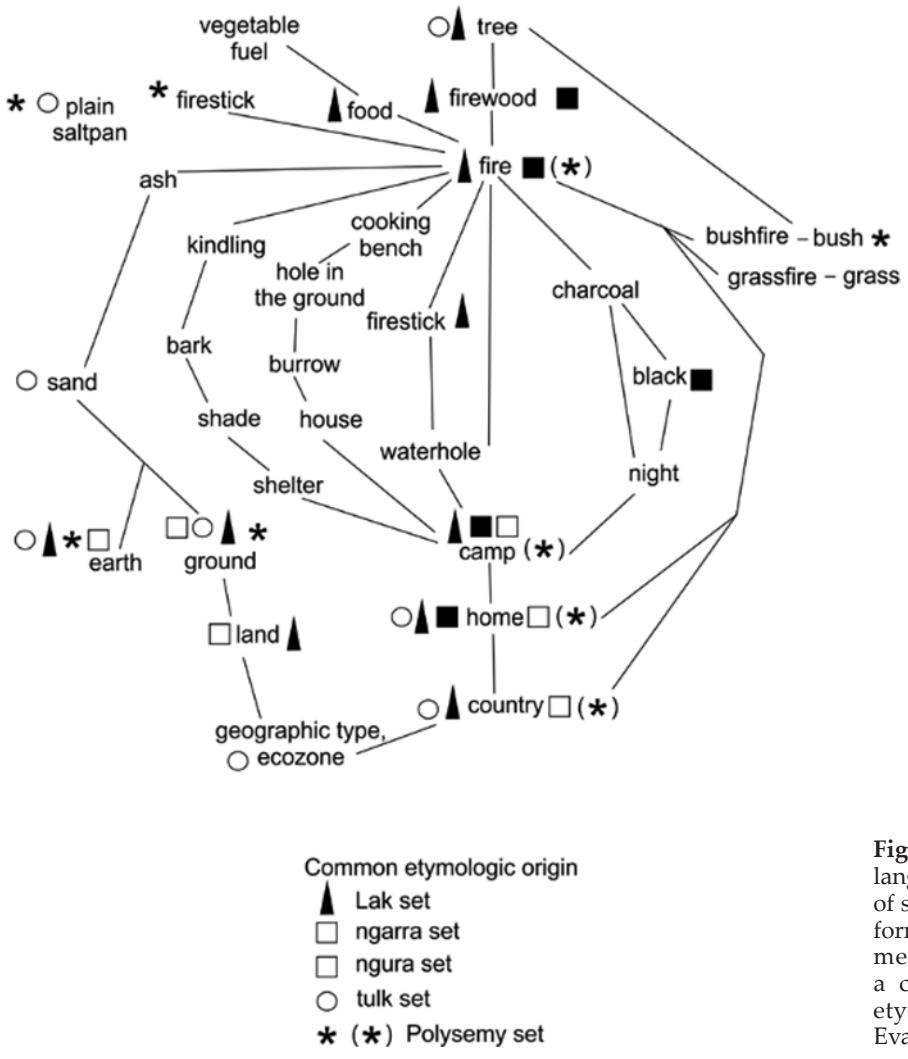

Figure 6. Part of the fire/camp/country language nexus representing networks of semantic connections. Lines indicate formal paths or connections between meanings, which themselves have a common linguistic derivation or etymological origin (modified from Evans 1992).

The pre-European fire regime in Australia is generally regarded as comprising frequent, low-intensity fires designed to increase the availability of resources (Gammage 2014) but, as Kelly (1998) explained for southern Western Australia (Noongar country), both frequent cool fires and less frequent, high-intensity fires are needed to manage the country. Cool fires (*karla nyidiny*) in early summer (*birak*) are aimed at promoting new growth, while still a little moist to force out animals (*barna*) and provide easier access through the bush (*marlark*) or country. Hot fires (*karla karlang*) are needed every decade or so, to maintain thick growth in some areas. The latter, however, are different to natural forest fires that sometimes result from build-up of undergrowth and have greater impact on soil organic matter and heating (Talua 2015). Kelly (1998, p. 12) also indicated that there are many other fire types, including those used for driving game, protection of upper canopy species, and making particular root crops more palatable (see also Scherjon *et al*. 2015).

Martu people of Australia's Western Desert, for example, have a rich language around fire that link people in their various life stages to landscape at different stages in the fire cycle, and the various methods for burning when hunting particular animals. *Nyurma* describes newly burnt ground, and *waru-waru* describes land where shoots have started to sprout; *mukura* (*nyukara*) occurs after a few years when edible plants are fruiting and seeding, and later still *mangul* commences when the growing spinifex starts to outcompete edible plants, leading to *kunarka* when the advanced spinifex starts to die and leaves behind sterile hollows (Bird *et al*. 2008; also https://www.kj.org.au/news/the-language-of-waru-fire). In short, fire is a word that encompasses an enormous variety of human activity with a wide diversity of cultural meanings and archaeological presentation, which is only just beginning to be explored.

CONCLUSIONS

Language is shaped by our need to communicate precisely and efficiently (Regier *et al*. 2016). The importance of fire for First Nations people has produced a wide vocabulary of associated words. It follows that an understanding of how First Nations Australians used, controlled, related to and thought about fire is a key part of interpreting combustion features in the Australian archaeological record (and may have important ramifications for interpreting similar features of gatherer–hunter–fisher communities elsewhere). One way to achieve this is through the combination of traditional knowledge and archaeological science, including micromorphology.

As Mentzer (2014) noted, micromorphology is not a panacea for making the identification and interpretation of fire in the archaeological record easy or simple. Nevertheless, it can reveal greater complexity in a site or sites, just as language associated with the word fire can also be demonstrative of great complexity. Such complexity is critical in providing a better understanding of the depositional and post-depositional history of combustion features and burned remains, and a more nuanced understanding of hearths as a cultural hub for past occupants throughout Australia. Whilst our review is not comprehensive, it does try to demonstrate that darkened charcoal or ash-rich features in archaeological excavations are as complex and nuanced as the language around fire and are worthy of greater attention and differentation.

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