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

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Abstract

Fire is a word that holds an enormous variety of human activity with a wide diversity of cultural meanings and archaeological presentation. The word *hearth* not only has links with fire but also as a social focus both in its Latin origins and in Australian Indigenous language, 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 words associated with fire from the different hearth types and fuel types to the different purposes of fire in relation to cooking, medicine, ritual or control of the environment. The archaeological expression of hearths and related combustion features is equally complex and nuanced but can be explored at the microscale using micromorphology. Here we aim to highlight the complexity in both language and micromorphological expression around combustion features using published and unpublished examples from archaeological sites in Western Australia. Our purpose is to discourage the over-ready use of the term hearth to describe charcoal and ash-rich features and encourage a more nuanced study of the burnt record in cultural sites.

Background

"*The hearth fire defined the human world…*" (Pyne 1991: 91)

Australia is a continent that burns regularly and burned or blackened features are common in Australian archaeological sites. Such burned or blackened features, with or without charcoal, are often interpreted as deriving from hearths or the remains of campfires. Whilst the term 'hearth' generally refers to *in situ* and intact combustion features, burned, blackened or ashy features that are less intact 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). Interestingly a search on the Scopus database using the keywords of 'Australia', 'archaeology' and 'hearth' returns 23 results but replacing hearth with 'combustion feature' only returns two (namely Wood et al. 2016 and Whitau et al. 2018). There is significant literature from fire science that makes it clear that not all fire is the same (e.g., Pyne 1991; Bowman et al. 2011; Scott et al. 2014). Instead, fire and the signature it leaves behind is influenced by the size and structure of the fire, temperature of combustion (hot fire or cool fire), the ability of oxygen to drive the combustion process (i.e. "clean burning"), the type of fuel burned (e.g., wood, leaves, dung, charcoal, etc.), and a range of other factors (March et al. 2014; Tulua 2015). The archaeological traces of fire are also influenced by the contexts and activities (trampling, dumping, raking out) in which people found fire useful and these contexts in turn shape the archaeological record that preserves it (Holdaway et al. 2017: S230).

First Nations people in Australia use fire in multiple ways, and the various words in Aboriginal and Torres Strait Islander languages describe the different types of fire, its behaviour and effects and also relationship of people with it. In Noongar the Aboriginal language of South Western Australia, the

definition of *karl/kaarla* is fire, whereas k*arluk*/*karlup* means 'place of fire or hearth' (figurative) but also 'home or heart country' (Kelly 1998). This focus around a *karl*, *kala* or fireplace is mirrored around the country, and indeed Pyne (1991: 91) denotes the hearth fire as the original of all other anthropogenic fires so much so that without it human society was unthinkable. Interestingly such terminology around fire as a social focus mirrors the Latin definition of 'focus' (from Latin) which literally means hearth or fireplace. There is also language around hearth types, such as the earth or ground ovens, which are known as *ilda* by Yura Yakarti people in the Flinders Ranges of South Australia (Walshe 2012), *kup murri* by Torres Strait Islander and Cape York people (Monaghan 2007)[1] or *mirnyongs* in eastern and south-eastern Australia (Chauncy 1878: 232). Earth ovens may be further distinguished by the different heating elements used and may be differentiated again from rock-filled pit-hearths (Fanning and Holdaway 2001; Rhodes et al. 2009) or surface fires. In other words, there is a distinction in language and purpose around fire and hearths.

Of course fire was not only used for cooking food; other fire types include light fire, warmth fire including bedside fire (Douglas 1988), hunting fire (e.g. Bird et al. 2008), signal fire (e.g. Gould 1971: 20), ceremonial and medicinal (smoking) fire (e.g. Kelly 2019; Musharbash 2018), and caring-for-country fire (e.g. Hallam 1975; Dortch 2005; Lloyd and Krasnostein 2006), with a rich terminology around these. As Hopper (2019: 8) outlines 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 recognized (Goldberg et al. 2017). One way to characterise and interpret combustion features in the archaeological record is through micromorphology. Micromorphology is one of the most useful techniques for investigating deposits formed through intensive human activity, including microscopic indicators of fire such as char, ash, bone, organic residues and heat-altered sediments in context with characteristics of sediment deposition and environmental processes (Mallol et al. 2017; Mentzer 2017). Micromorphology has been used to discriminate surface fires from ground (dug) ovens (e.g., Aldeias et al. 2016; Haaland et al. 2017; Whitau et al. 2017), single from multiphase hearth use (e.g., Meignen et al. 1989, 2007), and hearths from secondary ash dumps (e.g., Schiegl et al. 2003; Friesem et al. 2014). However, with few exceptions (Whitau et al. 2017), microarchaeology 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, from a range of published and unpublished archaeological sites. It should be noted that the two of the micromorphological examples of combustion features presented in this paper were obtained opportunistically from sites sampled during contractual work and only one as part of a dedicated research study in the Pilbara region of NW Australia. The main purpose of our discussion, which follows others in the same vein (Aldeias et al. 2012; Mentzer 2014), is to highlight the complexity

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

around combustion features as observed in archaeological excavation and discourage the over-ready use of the term hearth to describe these. 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

Indigenous earth ovens

Indigenous earth or ground ovens (heat-retainer hearths) involve many different types of heating elements, including lumps from termite nests (e.g., *Drepanotermes perniger*), lumps of baked earth (clay), calcrete nodules, stones, charcoal or coals (Clark and Barbetti, 1982; Pardoe 2003; Ross et al. 2019). Each of these have different cultural terms. In Noongar, for example charcoal is *kop*, coals *bridal* and white ash *yoort*. Firelighting may utilise firesticks (*boorna karla/karlmoorl*, *tjangi*) or stone (*boya*) and may involve the use of dried bark (*likarra*), dung (*kuna*) or grass. Each of these elements may have different micromophological expression (Mentzer 2017; Villagran et al. 2019). Villagran et al. (2019), for example, made use of micromorphology and micro-CT scanning methods to detect fragments of termite mounds in ash-rich archaeological sediments, as evidence of their possible use in earth ovens. The use of kangaroo dung, however, may be confusing as dung or spherulitic remains of this (e.g., Vannieuwenhuyse 2016) may be a result of natural or cultural processes.

In the Flinders Ranges of South Australia, *ilda* are earth ovens used to cook large game (e.g., kangaroo) using hot ash and charcoal (Tunbridge 1985). Citing Tunbridge (1985), Walsh (2012) describes how earth ovens were made by burning wood in a dug hole to form coals, 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.[2] Rocks were occasionally added, but these had been described ethnohistorically as dangerous due to their '*propensity to explode and embed ... in someone's flesh*' (Tunbridge 1985:19).

An early account of "Aboriginal Ovens" by Peter Beveridge (1869) describe 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 food is sealed with more damp grass and covered with hot clay and fine earth; 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. Indeed Ross et al. (2019) describe the formation of incipient (< 30 cm thick) 'earth mounds' or 'oven mounds' in the Murray-Darling Basin as a result of repeated use of earth oven cookery methods by First Nations people in the mid- to late-Holocene (see also Pardoe 2003; Martin 2011; see also Pyne 1991: 89). A study by Martin (2011: 163) in the Murray River plain reference the use of heat retainer ovens in mounds for cooking *Typha* sp. rhizome and other wetland plant foods. These ovens were known as *balyan* in the Wiradjuri (Central New South Wales) language (Richards 1902: 114) and *compung* or *gumbung* in the Wemba Wemba (north-western Victoria) language (Stone 1911: 444–45).

Temperatures obtained in the cooking process in these earth ovens are likely to be quite high (> 500°C), and should be reflected at macro- and micro-scale in the oven walls (Gur-Arieh et al. 2013),

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

as well as heat-fractured rock or altered bone (e.g., Shipman et al. 1984) (Table 1). Martin (2011), for example, used the frequent occurrence of fused silica particles and white (rather than grey) colour of calcined bone to indicate heating temperatures of between 600°C and 900°C in one of the excavated mound ovens. 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. 2006). Other features of earth ovens include partially-combusted plant matter, as well as more and larger, solid charcoal (e.g., Figure 1B) as a result of the low oxygen conditions, may or may not be present (e.g. Martin 2011; Whitau et al. 2018).

Figure 1 shows a sequence of (shallow) dug combustion features, defined as hearths, from an ancient site in the Kimberley (Whitau et al. 2018; see also Vannieuwenhuyse 2016). A sharp boundary and bedded, orientated particles at the base of the lowermost combustion feature (Figure 1C) is indicative of possible digging. Geogenic sediments 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; Figure 1). 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

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 and Lavi 2017). Cooking (*dookerniny* in Noongar) with surface fires (flat hearths) or dug hearths (pit hearths) may involve heat-retainer stones, direct roasting over hot coals (*karl*, e.g., snakes, small mammals, insects), or baking in the ashes (*karl-teerdup,* e.g., snakes, frogs, fish, dampers), hence may be expected to cover a broad range of temperatures. Food (e.g., fish, nuts) was sometimes wrapped in 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. An interesting example of cooking with ash is described by Meagher (1975) where waterfowl were covered with mud, placed in a hole, and then covered with ashes to cook for several hours. When the baked mud was cracked open the feathers came away in the mud leaving the body clean. Microscopic feather identification is possible, although it has not yet identified in the Australian archaeological record (Robertson 1992).

Unlike pit-hearths, surface fires are not dug into the substrate but 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., Figure 2). These burnt sediments are themselves sandwiched between unconsolidated surface sediments and an underlying ironstone unit, both into which burnt material has been mixed (Table 2). Whilst they may have many purposes, the assumption – especially where wood has been completely combusted, is they are mainly expedient fires for short-lived activities (e.g., Mallol et al. 2007; Friesem et al. 2017; Whitau et al. 2018).

Another purpose of surface fires is for steaming or smoking. Smoke (*karl boyi* in Noongar) is important in ceremonial and medicinal use to cleanse spirit, including smoking of babies after childbirth[3] and young boys after initiation (Richmond 1993; Musharbash 2018; Kelly 2019).

[3] See also Muluru (2001) https://www.nfsa.gov.au/collection/curated/smoking-baby-muluru

Smoking is also used for fumigation or (therapeudic) inhalation, a variation of which 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 and Jones 2016). To create smoke, leaves rather than tree wood is used. The leaves of *Eremophila longifolia* (Berrigan emu bush), for example, is one plant species particularly favoured for smoking purposes as it produces a smoke with significant antimicrobial effects (Richmond 1993; Sadgrove et al. 2016).

Figure 2 shows remains from a surface fire, with baked sediment below (but not above) ash and charcoal deposits. The presence of ash particles in anatomic connection (Figure 2A) is indicative of the fire being *in situ*, and that these structures were not used repeatedly (Mentzer 2014; Whitau et al. 2018; Friesem et al. 2014). The hearth and surrounding sediments contain high quantities (~20%) of carbonised and degraded (but unidentified) plant material, including root, stem and leaf tissue from which resin appears to have been exuded (Figure 2C). The possible evidence of resin in the deposit is interesting and may imply the purpose of the fire was medicinal or for tool making. Whilst occasional fragments of burnt bone are present, the predominance of plant material and small size of the hearth further implies cooking was not the main purpose. However, Walters (1988) has previously noted that fires of First Nations people are always kept clean and that bone and rubbish is never discarded into fires, hence absence of bone *per se* cannot be indicative of purpose.

Another interesting example of a site rich in plant material is shown in Figure 3. Excavation of this Pilbara rockshelter site revealed a series of relatively thin (< 2 cm) layered black, organic-rich units (approx. 30 cm across) that are interspersed with the otherwise relatively homogenous iron-rich silty sediments. Thin section revealed some dark units had 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 (Figure 3C – F) that may indicate burning of bedding/floor matting, smoking to repel insects, or some other repeated activity. Deposits may also contain bedded un-burnt 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).

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. Acacia sp.), 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; Sadgrove and 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 a number of 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 specific to fire making, including kapok (*Aerva javanica*), kerosene grass (*Aristida contorta*) and camel bush or *kalyartu* (*Trichodesma zeylanicum*). In Noongar country in southwest Western Australia, 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 may also be relevant to understanding past fire use. Studies around fire can obviously benefit from the combined use of micromorphology, anthracology or other plant identification methods (e.g. Whitau et al. 2018) alongside traditional knowledge.

Maintenance and secondary ash dump (rake out) features

In any open-air site or rockshelter or caves, the repeated or multipurpose nature of fire use involves some level of management, including from the extinguishing of the fire (*warrugalgu* in Ngarluma (coastal Pilbara)) to the rake out of hearths, sweeping and dumping of debris elsewhere (O'Connell 1987; Fisher and Strickland 1989; Friesem and Lavi 2017; Friesem et al. 2017)(Goldberg 2003). The micromorphological expression of a burning palimpsest will vary depending on the original nature and purpose of the fire and the type 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). More important is the complete lack of baked substrate that would otherwise indicate *in situ* burning (Schiegl et al. 2003; Friesem et al. 2014; c.f. Mentzer 2014). The importance of differentiating rake out features from *in situ* hearths is to highlight different use of space in and around archaeological sites (Friesem and Lavi 2017; 2019).

An example of a possible rake out site is shown in Figure 4. An excavation against one of the walls near the front entrance of a large cave off the Pilbara coast exposed a 50 cm-deep highly mixed deposit (Figure 4B) with significant post-depositional alteration from gypsum. Micromorphological analysis of the deposits revealed a mix of charcoal (Figure 4B), burnt and unburnt teeth and bone (Figure 4D), shell (Figure 4E), patches of ash (Figure 4F), and fine silts. Whilst these secondary deposits were not particularly notable in themselves beyond the variety of debris they contained, they were of interest because they were the closest associated feature to a hearth, which has yet to be unearthed at the site. In contrast to Schiegl et al. (2003), this rake out site is located close to the entrance and within the immediate area of occupation rather than further back in the cave. This likely increased the reworking of the deposit by burrowing fauna or possibly by humans, although there was little or no obvious trampled material in thin section.

Natural versus cultural features

The importance of identifying hearth features is particularly apparent in the site of Moyjil (Point Ritchie) in Victoria, postulated to date to the Last Interglacial (McNiven et al. 2018). 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 (refer their Table 3) but micromorphological analysis is still pending. The presence of rubified sediment or fire-cracked rock, charcoal and/or articulated ash lenses are all used to identify intact combustion structures or hearths but none are unequivocal indictors. However, the presence of cultural material including bone fragments of economic fauna, multiple charcoal taxa, ochre or exotic stone fragments tend to support the interpretation of human activity (see also Barbetti 1986).

Another elusive combustion feature are tree hollow hearths (Pyne 1991; Builth 2014). These involved the use of natural tree hollows or large eucalypt trunks that were sometimes culturally enhanced (through use of fire) to enable them to be used as ovens, smoking chambers or fire depots on a landform that could otherwise not be dug into and/or where climatic conditions made it very difficult to find any shelter to cook staple foods. Larger hollows could even be used for shelter (Pyne 1991). Evidence of cultural burning within natural tree hollows tends to manifest on 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 1991:90). Although not documented, it is possible the use of hollowed trees as a protected space for smoking, fires or shelter may also extend to the wet south-west corner of Western Australia where karri forests are endemic. 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.

Whilst the vocabularies of First Nations people contain many words for fire, they carefully distinguish the hearth fire from bushfire (Pyne 1991: 91). Differentiation of cultural and natural fire signatures in the sedimentary record is beyond the scope of this study, and work is ongoing in this area. Nevertheless, useful insights can be gained from language around cultural burning that may inform future micromorphological studies. 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) explains, both frequent cool fires and less frequent, high-intensity fires are needed to manage the country. Cool fires (*karla nyidiny*) in early summer (*birak*) were 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. These hot fires, 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). Potential exists to explore the differences in heating temperature of soil, and burnt elements contained within it (e.g. bone, charcoal) through use of FTIR (Berna et al. 2007; Weiner 2012; Ellingham et al. 2015). Kelly (1998: 12) reminds us 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.

Martu people of Australia's Western Desert also 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* occurs 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; see also https://www.kj.org.au/news/the-language-of-waru-fire). In short, fire is a word that holds an enormous variety of human activity with a wide diversity of cultural meanings and archaeological presentation which we are only just beginning to explore.

Conclusion

Language is shaped by our need to communicate precisely and efficiently (Regier 2016). The importance of fire in the economy of First Nations people has produced a wide vocabulary of fire 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 archaeological record. One way to achieve this is through the combination of traditional knowledge and western science, including micromorphology. Whilst our study is not comprehensive, it does try to demonstrate that darkened charcoal or ash-rich features in archaeological excavations are complex and nuanced, as is the language around fire.

However, as Mentzer (2014) notes, micromorphology is not a panacea for making the identification and interpretation of fire in the archaeological record easy or simple. Indeed, it is clear that it can

show greater complexity in a site or sites, just as language around the word fire can also show great complexity. Such complexity is critical in providing a better understanding of the depositional and post-depositional history of burned remains, and a more nuanced understanding of hearths as a cultural hub for past occupants throughout Australia.

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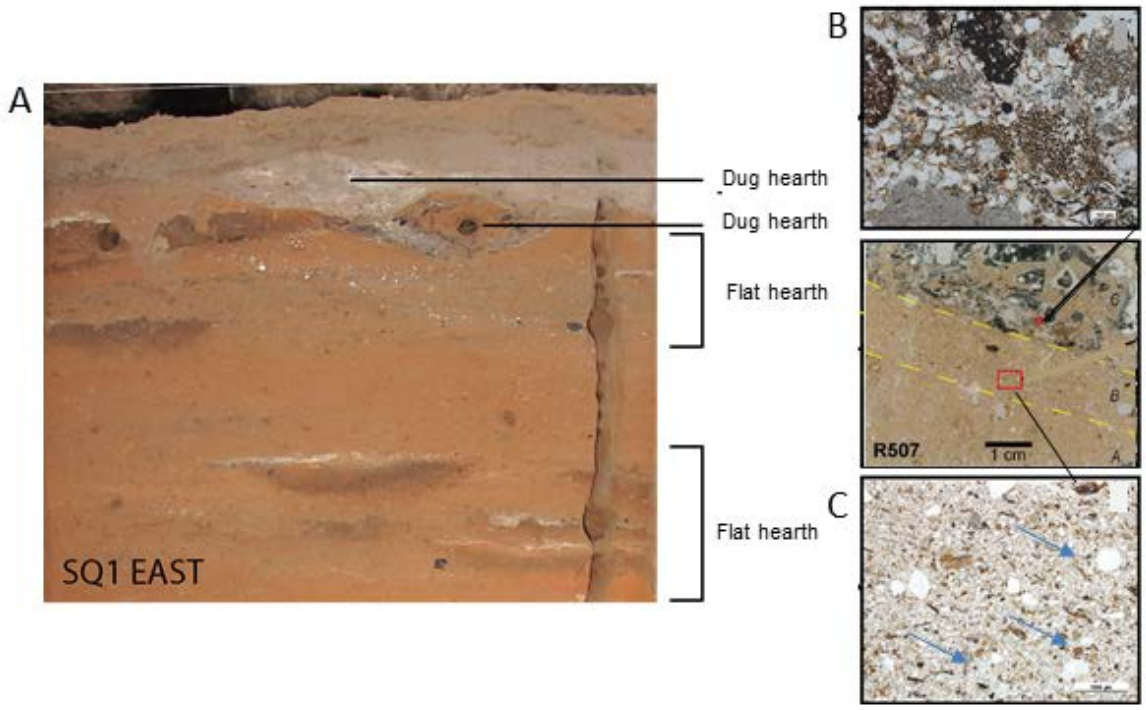

Figure 1 **A**. Field photograph showing a dug hearth overlying surface fires (flat hearths) in an excavation profile from the Kimberley region. The sharp transition at base of hearth s evident within the thin section R507 from this profile. Micropictographs from the thin sections show **B.** mixed charcoal fragments, ashes and geogenic sands (PPL, scale 100 µm), and **C**. bedded organic particles below the combustion feature that could indicate digging (PPL, scale 1000 µm) (modified from Whitau et al. 2018; their Figure 8).

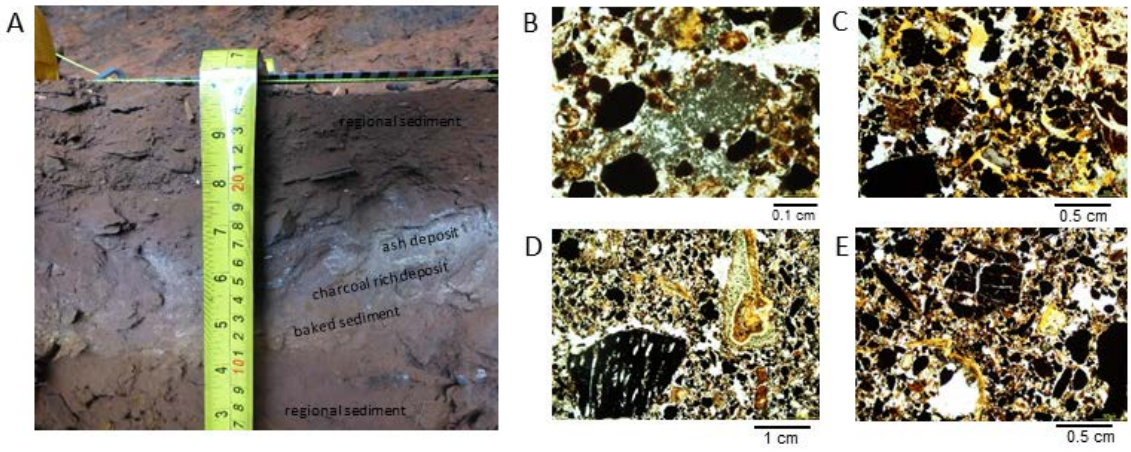

Figure 2 **A**. Field photograph showing a typical in situ hearth from a shallow excavation profile in the Pilbara, showing remains of one or more burning events represented by charcoal and ashes overlying baked sediments. A series of thin sections micropictographs taken in Plane-Polarized Light (PPL) from this profile show **B**. rhombic ash in anatomic connection, **B**. possible resin, **C**. humified plant material and charcoal fragments, and **D**. fire-cracked rock.

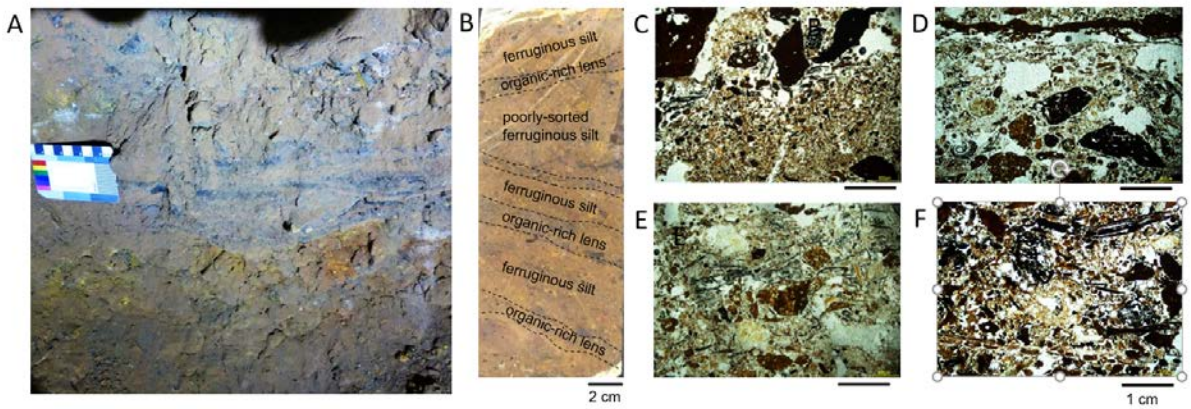

Figure 3 **A**. Field photograph of an excavation profile from a Pilbara rockshelter site showing a sequence of charred plant laminae interposed between ferruginous silty sands. **B**. Scan of the resin-impregnated block showing repeated (up to 9) microstratigraphic units. A series of micropictographs from the thin sections taken in Plane-Polarized Light (PPL) showing **C**. laminar plant char over fine silt; **D**. laminar plant charcoal and ash; **E**. probable fine leaf matter, mixed with some bone; and **F**. articulated laminar plant char and humified plant material. Scale bar is 1 cm.

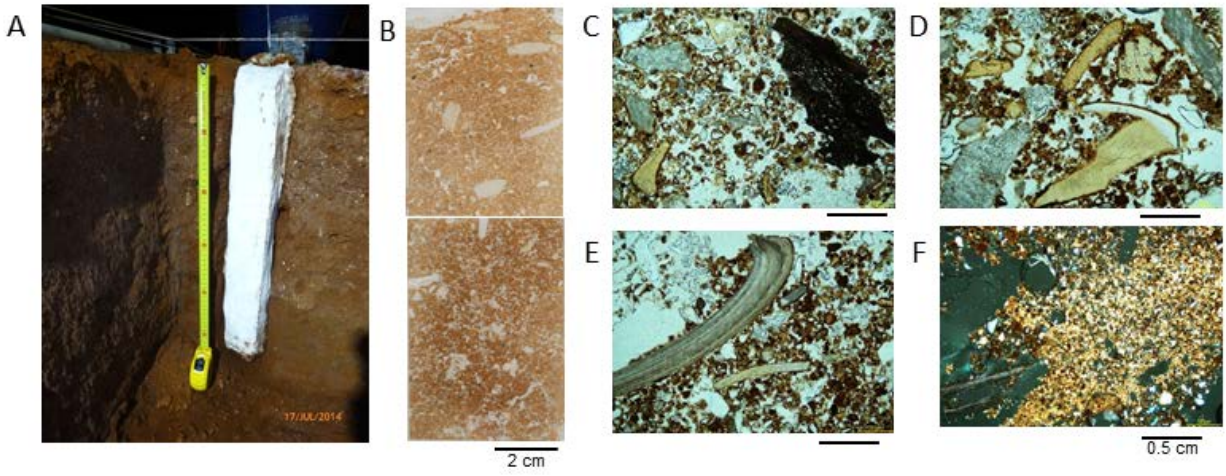

Figure 4 **A**. Field photograph showing resin profile sampling of a probable dump site, positioned against a rockshelter wall. **B**. Thin sections show a largely homogenous sediment profile. Micropictographs from thin sections within this profile show **C**. plant/charcoal and bone fragments in a matrix of limestone and fine clay (PPL); **D**. tooth and bone fragments (PPL); **E**. shell and bone fragments with gypsum in voids (top left) (PPL); and **F**. concentrated area of micritic ash (XPL). Scale bar is 1 cm unless indicated otherwise.

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

Combustion type	Archaeological expression Macro	 Micro	Taphonomy	Possible function
Earth/rock oven (*Ilda; kup murri; mirnyong*)	• 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*[i]*; waru kurrkaltju*[ii]) • Tool manufacture (?)
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*)[ii] • Quick cooking, e.g. opening shellfish • Light (*nyurnmatjali*)[ii] • Warmth (*yakunpa*)[ii] • Social hub
Shallow pit hearth (*karlup*)[i]	• 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 ~300 – 600°C	• Shallow hence high post-depositional alteration	• Cooking (*dookerniny*) including roasting, broiling, hot ash • Light (*nyurnmatjali*)[ii] • 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 • 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	• May be reworked or bioturbated	• Cleaning by-product

	• Partially-burnt material • Low geogenic content • High porosity • Slight orientation of charcoal grains		

[i] Language of South West Australia (Douglass 1996)

[ii] Language of Western Desert (Douglass 1988)