Direct dating of resin hafted point technology in Australia

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Abstract

The rare recovery of hafting technology from archaeological deposits around the world prevents a clear picture of Palaeolithic hafting arrangements. Without the recovery of hafted stone tools, our understanding of this technology is limited to extrapolation from artefact morphology and ethnographic analogy, and such is the case in Australia. Here we present a direct date of 3160–2954 cal. BP, obtained from resin on a stone point recovered from Carpenters Gap 1 rockshelter in northern Western Australia. This artefact fits the description of point technology in Australia, being a retouched flake with converging margins, and provides the first direct date of hafting resin in situ on a stone tool from the Australian continent. The hafting arrangement of a stone point during the mid- to late Holocene is archaeologically visible for the first time in Australia. This point was hafted using resin adhesive as well as wound binding material. This rare artefact is used to discuss the current interpretations of technological change in the Holocene record of Australia and the direct dating process.

Introduction

Excavation at Carpenters Gap 1 (CG1), a site with exceptional organic preservation in the southern Kimberley, Western Australia (McConnell and O'Connor 1997, 1999; O'Connor 1995; Wallis 2001) (Figure 1), recovered a distal point fragment with a sizable portion of adhering resin with imprints of an organic binder. This paper presents the results of direct dating of the resin and a description of the imprints and stone artefact. This is the first Australian stone tool to be directly dated using adhering resin and demonstrates how this method can be used to provide reliable ages for a range of Australian composite tools, as well as assist us to understand hafting technology better.

Unifacial and bifacial points first appear in parts of Australia in the mid-Holocene (Hiscock 2008:158; Maloney et al. 2014), although the dating of the appearance of these tools (and other hafted tools) has not been without contention. Points are widely identified as retouched flakes with converging margins (Hiscock 2006:76; Holdaway and Stern 2004:266). Dating the appearance of this technology has conventionally relied on dating organics in associated excavation units. In sandy deposits, however, the assumption of association is problematic, as bioturbation and other disturbance can lead to vertical movement of objects up and down the profile (e.g. O'Connor et al. 2002; Richardson 1992). Direct dating of resin has the potential to provide reliable ages for the diversity of hafted tools that appear across Australia in the Holocene.

The impressions preserved in the resin of the CG1 point also provide evidence of the methods involved in its hafting, indicating the use of organic binders as well as mastic.

The process of hafting was a crucial technological development in human evolution. The expansion of hominid populations resulted in the adaptation of hafting technologies to a myriad environmental, social and economic conditions across the globe. A vital component of the toolkit (Shea 2006), hafted technology is still employed by some hunter-gatherer groups today (Weedman 2006). Despite the ubiquity of hafting technology, direct evidence of hafting in the archaeological record is rare, limiting our understanding of how this technology was adapted to novel conditions.

Archaeologically, there are three elements that can provide evidence of hafting: the tool itself, the haft and the binding agent. The earliest evidence for hafting technology is based on diagnostic impact fractures on tools, such as those fractures found on points excavated from the Kathu Pan 1 site in South Africa and dated by association to 500,000 years (Wilkins et al. 2012:943; see also Barham 2002). The earliest spear shafts were recovered from the Schöningen site in Germany (Thieme 1997), dated to 400,000 years, but no lithic projectiles were recovered, prompting the authors to conclude that the spears were fashioned entirely from wood. The earliest organic evidence of compound hafting matrix was identified on Middle Stone Age tools, dated to 70,000 years, from Sibudu Cave in South Africa (Wadley et al. 2009:9590). Birch tar residues have been recovered on

Figure 1 Map of north Western Australia showing site location.

stone tools from several European Palaeolithic sites (Boëda et al. 1996; Mazza et al. 2006; Pawlik and Thissen 2011:1707), including a birch tar piece with impressions of a stone tool, a wooden artefact and fingerprints (Grünberg 2002; Hedges et al. 1998; Koller et al. 2001).

Recovery of early hafting technology throughout Asia has been rare and few studies demonstrate composite tool use before the terminal Pleistocene. In Timor Leste, the butt end of a bone projectile from Matja Kuru 2 (MK2) has been dated to ca 32,000 cal. BP, by association with radiocarbon dates of marine shell (O'Connor et al. 2014b:110–111). This artefact preserves evidence of a complex hafting mechanism, which employed an organic fibre wrapped around a mastic on the bilaterally notched butt. At Niah Cave in Borneo several bone and stingray spine points, with traces of hafting resin and fibrous binding, have been dated to the terminal Pleistocene, based on association with charcoal radiocarbon

dates (Barton et al. 2009:1708–1709). Hafting of backed artefacts using resinous mastic was practised in the late Pleistocene at Jwalapuram Locality 9, in India (Clarkson et al. 2009:334, 339), but only a few of the recovered artefacts retained resin, inhibiting a convincing interpretation of the composite arrangement (Clarkson et al. 2009:339). The only other direct evidence for early hafting comes from northern China where use-wear analysis on adzes and projectile points indicates that these artefacts were used in composite tools from around 10,000 years ago (Zhang et al. 2009).

The earliest colonisers of Sahul, who employed complex seafaring technology (Balme and O'Connor 2015), are likely to have been adept at fibre processing and resin manufacture and use. On encountering new environments these early settlers developed new hafting technology and made edge-ground and waisted axes, since whole axes and flakes detached from them have been recovered from the

earliest levels of some of the oldest sites in northern Australia (Clarkson et al. 2015:59; Geneste et al. 2012:2; O'Connor 1999:175; O'Connor et al. 2014a:18; Schrire 1982:84, 106–107). McConnell and O'Connor (1997:24–27) suggested that the abundance of resinous spinifex culms in the Pleistocene assemblage at CG1 may indicate early resin production for hafting. Prior to the CG1 point discussed here, the only direct dates obtained from manufactured resin in Australia have been reported from surface assemblages in the Pilbara, WA (Veitch et al. 2005:60, Table 1), where two spinifex balls were dated to within the last 1000 years. Despite the continuing dearth of physical evidence, hafting remains central to explanations of technological change in Australia.

The mid-Holocene has long been recognised as a period of dynamic technological and social change across the continent of Australia, with either new forms of stone tools or the proliferation of existing stone technologies becoming widespread. Most of the evidence for hafting technology has been extrapolated from tool morphology. A generally small size, pointed termination, elongation and proximal thinning of many tools have led some archaeologists to argue that hafting was a central technological requirement of these tools (e.g. Allen and Barton 1989:121; Clarkson 2007:155, 2008:302; Clarkson and David 1995:22; Flood 2004:225; Hiscock 1994:277; Mulvaney 1969:153; Mulvaney and Joyce 1965). Innovation in hafting techniques was hypothesised as an overall explanation for new stone tools across the continent during the mid-Holocene (Jones 1979:456–457; Mulvaney 1969:153). The implied hafting of points and backed artefacts was also used to argue for increased conflict (Flood 1995:236; Smith 1995:40; Smith and Brockwell 1994:102). Recent explanations of the development of points and backed artefacts tend either to support a technological response to foraging risk (Clarkson 2007:155; Hiscock 1994:277; 2011), and/or a social response to demographic changes (Moore 2013; White 2011). Hafting features prominently in both scenarios. The foraging risk model argues that points as standardised implements allowed continuous hafting and rejuvenation within the same costly, pre-designed hafting arrangement (Clarkson 2007:155, 2008:302; Hiscock 1994:278). Social signalling explanations, on the other hand, suggest that points were hafted as highly visible symbols of identity and social status (Moore 2013:145).

Points are a likely candidate for hafting as projectiles due to their shape, although it is also apparent that points were used for a range of functions both with and without other hafting arrangements. Limited resin recovery has hitherto prohibited reconstruction of hafting arrangements. For example, the only residue analysis of points thus far carried out yielded two of 42 points with possible traces of hafting resin but no dating of the resin was attempted (Wallis and O'Connor 1998:10). Additionally, while hafting is largely inferred from the morphology, the pointed shape was not always maintained (Clarkson 2007:112, 114, 117; Hiscock 2009:84–85; Maloney and O'Connor 2014). Macrofracture analysis of points from the Northern Territory reveals that mid-Holocene points may rarely have been used as hafted projectiles (Brindley and Clarkson 2015). Conversely, a few studies that showcase hafting resins on backed artefacts were able to confirm that multiple hafting arrangements were employed (Boot 1993:5, Tables 8–11; Brown 1987:49; Robertson et al. 2009:249, 297) with projectile tips or barbs utilised less frequently (McDonald et al. 2007).

Without over-extending the application of ethnographic analogy (Binford 1972:86), more recent and museum curated examples of stone tool hafting can be informative. In northern Australia, ethnographic observation and collection have provided useful insights into recent forms of point hafting technology (Akerman 1978:486; Akerman et al. 2002:21–22; Hardman 1888:64–64; Kaberry 1939:14; Newman and Moore 2013). For example, Akerman (1978:486) described the ethnographic hafting of Kimberley points, which are present in archaeological deposits around 1000 cal. BP (Maloney et al. 2014). Other forms of point and blade hafting described by Newman and Moore (2013:2615, Fig. 1), Spencer and Gillen (1899:652), Graham and Thorley (1996:78–79), Bindon and Lofgren (1982:119, Fig. 6), and McCarthy et al. (1946:32), demonstrated that, in recent times, multiple hafting arrangements were used. Ethnographers such as Roth (1897, 1904) provided accounts of hafting a range of stone artefacts, including what would not be recognised as formal tools (see Khan 1993). There are also examples of handles created from mastic and binding, with no incorporated shaft (Newman and Moore 2013:2615, Fig. 2), and large blades hafted as knives (Akerman 2007).

Sources of Resin in Australia

Ethnographically, resins were observed being extracted from a range of plant species across Australia (Aiston 1929:45; Boot 1993:5; Latz 1995:341; Maiden 1975; Parr 1999:23; Richardson 1988:58). In the Kimberley, resin was extracted from *Triodia pungens* (spinifex), the roots of *Erythrophleum chlorostachys* (ironwood), and *Callitris columellaris* (native cypress pine) (Akerman pers. comm. 2014). Other sources of resin include native bee (*Trigona* sp.) hives (Akerman pers. comm. 2014) and ant nests (Akerman 1980:246; Latz 1995:290; Lowe and Pike 2009; Spencer 1896:69–71), probably produced by *Iridomyrmex rostrinatus* (Butler 1966). The use of ant nests for resin production is possibly a more recent technological development (Pitman 2010:89–91). Again, more recently, burnt battery cases and tar from sealed roads were used in hafting technologies (Akerman 1980:246). In north Queensland, the young roots of the ironwood tree *Erythrophleum labouchei* were processed for resin production (Khan 1993:87). In the same area, Roth (1897) noted dry lumps of gum gathered from the brown cedar or mackay cedar tree *Canarium australasicum*, which were used for joining spear shafts (see Khan 1993:130).

Spinifex resin, a thermoplastic adhesive, is the most prolific source of plant resin in Australia (Pitman 2010; Pitman and Wallis 2012). The threshing of spinifex, in order to extract the resin, was practised across much of the continent where resinous spinifex occurred (Binford 1984; Brokensha 1975; Cleland 1966; De Graaf 1967; Gould 1970; Pitman 2010:31–39; Roth 1904; Sheridan 1979; Tindale 1965). Spinifex grass was threshed on a hard surface and the resulting resin-chaff mixture was collected in a container (Binford 1984:161–171; Gould 1970:39–40; Latz 1995:66, 290). This mixture was then winnowed, which freed scales of resin from the leaf bases. The mixture was then heated using a variety of techniques (Pitman 2010:36) and metamorphosed into a homogenous cake of resin (Cleland 1957, 1966:122, 146–147; Roth 1897:101–102, 1904:13).

Inclusions of chaff in resin are a reasonable visual indicator that the resin source was spinifex grass (Pitman 2010:102;

Sheridan 1979:67). Other inclusions, such as sediment grains, ash, charcoal, saliva, animal fat and blood are also possible. Ochre and bird feather decorations are present on recent Kimberley points, variably covering the shaft and mastic (Akerman et al. 2002:23–24; Newman and Moore 2013:2616, Fig. 3) and have been detected on at least one mid-Holocene point (Wallis and O'Connor 1998:160, Table 2).

The CG1 Hafted Point

The hafted stone tool illustrated in Figure 2 meets the descriptive criteria for point technology based on several observations. Firstly, the distal portion of the tool can be observed projecting from the resin, with an intact feather termination and partial ventral surface, confirming that the tool is technically a broken retouched flake (Hiscock 2007:203). Secondly, retouch scars initiated uniaxially from the ventral surface are present on the left distal margin, which, combined with the unretouched right margin, create converging margins. The marginal angle (approximately 63°) is within the morphological range of other retouched flakes described as points, such as those found throughout the Kimberley (Dortch 1977:166, Fig. 5; O'Connor 1999:73–74, Fig. 5.13, Fig. 5.14; O'Connor et al. 2008:79–80, Fig. 4.) and in Wardaman Country, NT (Clarkson 2006:102). Prior to breaking, the point was probably very similar to those recovered from the nearby Windjana Gorge Water Tank Shelter (O'Connor et al. 2008:79–80, Fig. 4) and Carpenters Gap 3 (O'Connor et al. 2014a:21, Fig. 10), being less than 4 cm in length and not particularly elongate. None of the

retouch scars are covered by the resin, so it is possible that the tool was hafted with no retouch and later modified.

The resin adhering to the dorsal surface of the point has been impressed, resulting in several clearly visible parallel lines on the proximal left surface (Figure 2). Each impression is approximately 0.3 mm wide, with the deepest penetration of the resin observed closest to the proximal edge. These impressions continue diagonally across the surface of the resin, with reduced penetration towards the right distal portion. These impressions were produced by a thin, fibrous material, which further bound the tool to the haft. The binding material covered around half of the remaining resin, and presumably continued over the shaft portion. The impressions do not intersect.

There are small pieces of plant material within the resin (Figure 2), which provide reasonable evidence that the resin was produced from spinifex chaff. Additional inclusions of small black and red flecks, around 1 mm², are possibly charcoal and ochre (Figure 2).

A negative flake scar initiated from the left medial margin propagates through the mid-section of the point and truncates the resin (Figure 2). This flake scar terminates before reaching the opposite margin (Figure 2), where resin can be seen covering part of the right margin. This small amount of resin is therefore covering a surface that predates the mid-section break and indicates that the right margin was contracting towards a probable platform surface. The implication of this observation is that the proximal portion is

Figure 2 Point from CG1 showing transverse scar across midsection, impressions formed by binding materials and small pieces of plant, probably spinifex chaff, in the resin (photograph by Tim Maloney).

unlikely to have been much larger than the remaining distal portion, leading to the estimated shape of the proximal portion used in Figure 3. It is possible that this scar was caused from projectile impact, given the resemblance to transverse scars observed on other hafted points (Ahler 1992:45, Fig. 11; Lombard 2005:225; Lombard et al. 2004). No other diagnostic impact fractures are evident. This fracture is perhaps less likely to have been caused during manufacture, following Ahler (1992:42, 56, Fig. 8), who demonstrated that transverse snaps observed on manufacturing failures will typically intersect or truncate retouch scars. This is not the case on the CG1 point. It is also possible that this break occurred while the tool was hafted for a non-projectile function, such as a cutting tool or drill. Given the nature of the material, crystal quartz, it is equally plausible that an incipient fracture plain propagated this transverse fracture.

The observed resin did not encapsulate the pointed distal tip. This distal portion of the tool was the only observed part to have been modified. Therefore, we can be certain that the point was hafted to utilise the acutely angled tip with converging margins, and potentially facilitated drilling, cutting and projectile functions. This assumption, in conjunction with the binding impressions and the mid-section break, was used to produce the hypothetical hafting arrangement illustrated in Figure 3. Figure 3 also shows how the binding agent may have increased resistance across the mid-section of the point, initiating the break (following Fauvelle et al. 2012:2807, Fig. 5).

Dating

The excavation units (EU) surrounding the point were formed between 3632 and 2850 cal. BP, based on multiple radiocarbon dates from charcoal (Table 1). Charcoal was dated at the ANU lab in the 1990s (laboratory code ANU) and the resin directly dated more recently (laboratory code SANU). All dates have been calibrated in OxCal version 4.2 (Bronk Ramsey 2009), using the SHCal13 curve (Hogg et al. 2013), with ranges given at 95.4% probability.

The CG1 point was recovered in Unit 8c, a layer rich in organic matter including paper bark and other plant materials, and was removed separately from the surrounding sedimentary units. This unit produced a date of 3632–3365 cal. BP (ANU-10030). The EU immediately above this, EU 8, dates to 3441–3076 cal. BP (ANU-10029). A hearth feature (EU 8b) truncating EU 8 dates to 3209–2927 cal. BP (ANU-11421). It is possible that the point comes from the interface of Units 8b and 8c. EU 9, which produced a date of 3557–3165 cal. BP (ANU-11460), is adjacent to, or immediately underlying, 8c. EU 10 produced a date of 3463–3164 cal. BP (ANU-11462).

The resin sample produced a calibrated age range of 3160–2954 cal. BP (SANU-39030) (Table 1). A 5.4 mg piece of resin, free from visible inclusions, was taken from the right ventral margin with a scalpel. This sample was subjected to a very gentle acid-base-acid pre-treatment to remove likely contaminants: HCl (0.1 M, 30 minutes, room temperature

Figure 3 Hypothetical hafting arrangement and impact forces, based on specimen observations.

Lab No.	EU	Material	Methods	$\delta^{13}\text{C}$ (‰, VPDB)	Radiocarbon date (BP)	Calibrated age (cal BP, 95.4% probability range)
ANU-11421	8b	Charcoal	Conventional	-	2960±40	3209–3191 (1.7%) 3185–2927 (93.7%)
ANU-10029	8	Charcoal	Acid wash, Conventional	-24.0±2.0 ²	3110±60	3441–3431 (0.7%) 3402–3076 (94.7%)
SANU - 39039	8c	Resin on point	Acid-Base-Acid, AMS (see text)	-18±2.0 ¹	2950±25	3160–2954
ANU-10030	8c	Charcoal	Acid wash, Conventional	-24.0±2.0 ²	3300±60	3632–3365
ANU-11460	9	Charcoal	Acid-Base-Acid, Conventional	-24.0 ± 2.0	3180±70	3557–3531 (1.9%) 3510–3165 (93.5%)
ANU-11462	10	Charcoal	Acid-Base-Acid, Conventional	-25.6±0.1	3160±60	3463–3164

Table 1 Radiocarbon dates from CG1, Square A1. Calibrated in OxCal v4.2 (Ramsey et al. 2009) against SHCal 13 (Hogg et al. 2013).

[RT]), NaOH (0.1 M, 45 minutes, RT), HCl (0.1 M, 30 minutes, RT), with three washes in ultrapure MilliQ™ water between each treatment. The base wash appeared to dissolve the resin, but also caused the dark resin to turn a pale cream colour, and highlighted an unidentified black fleck, possibly some form of charred material. The treatment decreased the sample weight to 1.32 mg (24% yield). The freeze-dried product, excluding the black fleck, was combusted in an evacuated quartz tube in the presence of silver foil and CuO wire at 900°C for 6 hours. The CO₂ was then collected and purified cryogenically before reduction to graphite with H₂ over an iron catalyst for measurement in a NEC Single Stage AMS (Fallon et al. 2010). The sample contained only 16% C, calculated volumetrically during cryogenic collection. The graphite weight was correspondingly low (0.21 g), but is within the range of sample weights routinely dated at the ANU.

Resins are rarely radiocarbon dated, and the ability of this specific pretreatment method to remove contamination added in the burial environment from a sample is not conclusively established. However, resins often give ages in agreement with other materials. For example, a radiocarbon date on resin of pine origin from a late 4th century Roman shipwreck agreed with the date of a coin embedded in the resin (Beck et al. 1994). Resin on a microlith from Border Cave (South Africa) (OxA-X-2418-47, 35,750±500 BP) gave an age in accordance with others from the same context on other materials without any pretreatment (D'Errico et al. 2012). In contrast to this Pleistocene example, large amounts (>1 %) of contamination are required to shift the Holocene-aged date from CG1 outside of its reported error.

A second problem may relate to the inbuilt age of the resin. As spinifex resin can be collected from ant nests, it could have an inbuilt age either from inclusion of old material, such as old wood charcoal brought into the nest, or from the use of resin from old ant mounds. On its own, the date should be treated as a maximum age for the hafting event. However, given the broad agreement between the dated resin and charcoal from surrounding contexts, it is unlikely to substantially overestimate the age of the hafting event.

Discussion

The CG1 point is the first directly dated hafted stone tool from the Australian archaeological record, providing the most conclusive evidence for mid-Holocene point hafting methods to date. The direct dating showcases the potential to date small samples of resin found on stone tools (5.4 mg) effectively, which in turn will provide better understanding of the chronology of hafting technology.

The hafting arrangement of the CG1 point can be reconstructed from fibre impressions preserved in the resin and analysis of the mid-section break. The impressions indicate that the hafting of this point incorporated some form of binding over the top of the mastic, unlike ethnographic examples (Akerman 1978:486; Tindale 1985:16, Fig. 1.10), where fibres were either wound onto the shaft before the application of mastic, or avoided entirely. Measurements of the impressions show that the fibre was probably fine strands of sinew or plant, less than 0.3 mm in diameter, that were wound around the resin. The resin itself was probably a spinifex product, given the observation of probable chaff, implying other technological actions, including spinifex threshing, and metamorphosis into resin through heating.

The CG1 point's mid-section break was probably initiated by resistance created by the fibrous haft at the mid-section and was possibly produced by a projectile impact. It is also possible that applied pressure to the distal end was caused in any number of other functions, such as cutting or drilling, and produced a similar breakage. We would like to stress, firstly, that, while the CG1 point is an evocative example of projectile technology, it could very probably have had other functions throughout its use life, and, secondly, this hafting arrangement should not be used as a standard for the hafting of all mid to late Holocene points.

What this hafting arrangement can reveal within current explanatory models of point technology is limited, although worthy of some discussion. Points first appear in the Kimberley by at least 5200 cal. BP (Maloney et al. 2014). Rejuvenation of broken points is more likely to occur when access to replacement materials is scarce (Andrefsky 2010; Hiscock 1988), such as forays away from the CG1 site into areas where suitable point producing material was less available. Andrefsky (2010:18) noted that the archaeological recovery of points with impact damage suggests people could afford to discard the point fragment and replace it with a new point. The discard of the CG1 point could therefore relate to relatively low pressures on point rejuvenation at the time. Alternatively, its discard in proximity to locally available crystal quartz sources could simply indicate that raw material availability made rejuvenation of small points unnecessary.

Because the CG1 point is small in size, was only lightly modified and discarded without rejuvenation, it seems unlikely that this artefact attained high symbolic value and information exchange potential (Moore 2013:145). The small size of this point makes recognition of retouch only possible by close examination, which suggests that retouch was unlikely to be a requirement of social signalling via point technologies. Rather, retouch of pointed forms, with undoubted potential as social signals, was more likely focused on working edge and tip maintenance.

Conclusion

The life history of points in Australia during the mid-Holocene is beginning to be understood better with reduction-based analyses and experimental use-wear. The central role of hafting in the explanatory models of technological change surrounding point technology in the Australian record can only be expounded by the recovery of rare artefacts such as the CG1 point reported here. The dating and analysis of the mastic on the CG1 point demonstrates the huge potential of this method for elucidating the timing and nature of this technology throughout the world. Complexities of dating residues on stone tools involve the ability to remove contamination added in the burial environment, but more particularly the unknown inbuilt age. For these reasons, the direct date of resin should be treated as a maximum age for the hafting event.

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