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Tracking an exotic raw material: Aboriginal movement through the Blue Mountains, Sydney, NSW during the Terminal Pleistocene

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Abstract

A compliance-based excavation on Parramatta River (western Sydney) found evidence of a brief visitation by Aboriginal people during the terminal Pleistocene (c.14 ka), from which an exotic raw material–medium-grained porphyroblastic andalusite-cordierite hornfels–was recovered. This raw material is rare in the region, only found in the Megalong Valley situated some 75km west of the site in Parramatta, and separated from the site by the Blue Mountains – a 40km wide, 1km high dissected sandstone upland. Historical observations and geological evidence suggest that the Coxs River, which runs through the upland, formed the probable connection between the two locales. The formation of the site at c.14 ka, along with our broader understanding of the region, suggests that the upland was only explored after the Last Glacial Maximum (LGM) and that the Great Dividing Range may have formed a significant barrier to early peopling of Sahul. Further, a delay between the end of the LGM and the exploration of the region implies populations were severely affected by the event and required considerable time to recover. The coincident timing of rapid sea-level rise from Meltwater Phase Pulse 1A and an increased supply of moisture associated with the Antarctic Climate Reversal at the time of many site initiations may have been factors in the upland and south west slopes visitation. Finally, the movement of the unusual hornfels artefact provides a coarse indication of the ranging territory for hunter-gatherers living in a temperate region (c. 8,000 km2) at this time. This is probably a lower estimate but begins to provide a quantitative value with which to begin to ratify the increasing divergence between archaeological and genomic studies in their definitions of mobility, sedentism and regional nomadism.

Keywords

Compliance-based archaeology; Parramatta River; alluvial terrace; exotic raw material; medium-grained porphyroblastic andalusite-cordierite hornfels

Introduction

The Blue Mountains is a dissected sandstone plateau, situated c. 70km west of the Sydney Central Business District (CBD), and forming part of the broader Great Dividing Range running along the eastern seaboard of Australia. Some 40 km wide with mountain peaks over 1,000m high and valleys >700m deep (Figure 1) (Herbert and Helby 1980; Johnson 1979), it formed a significant barrier to the settlement of Sydney and exploration of the continent in the late 18th and early 19th centuries. Despite repeated attempts, Blaxland, Lawson and Wentworth were reportedly the first Europeans to find a route over the mountains in 1813, some 25 years after the establishment of the Sydney colony (Blaxland 1813 [1913]); and even today their route remains one of only two formalised ways to cross the mountains. However, there are some suggestions of an earlier passage by a former convict, John Wilson, guided by Aboriginal people along the Coxs River corridor–a large water course that runs in a southern arc between Megalong and Warragamba (Cunningham 1996). Indeed, several explorers noted the presence of Aboriginal people in the vicinity of this river corridor during this period, with evidence taking the form of the remains of fireplaces (Barrallier 1802 [1975]), huts and fires (Blaxland 1813 [1913]). More recently, an unpublished oral history from the 19th century describes that the river followed a portion of a *Gundungurra* Dreaming story (Smith 2009). However, our knowledge of when this route was initiated, or broader past Aboriginal activity within and/or through the mountain range, is less well understood – in part due to the early inundation of key locales for Sydney's water supply.

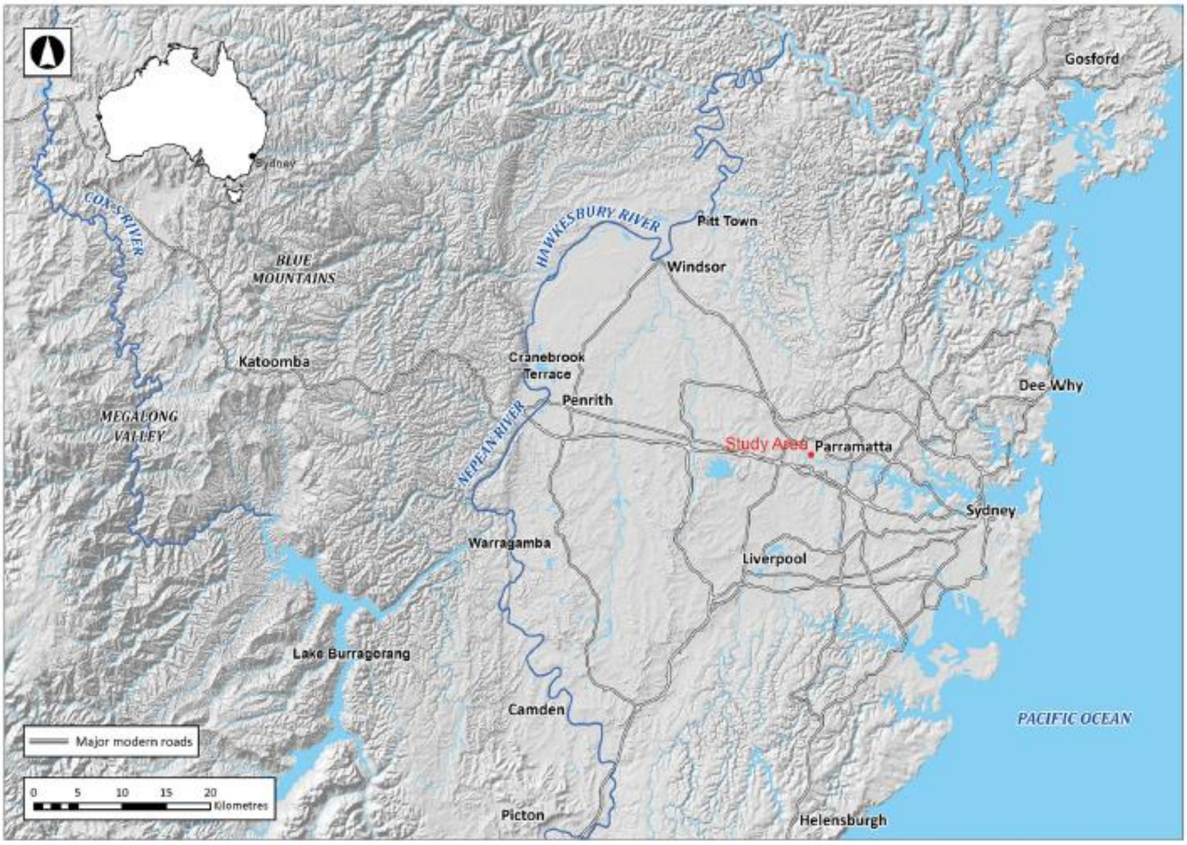

Figure 1 Location of the study area, and places discussed in the text. Coxs River has been inundated by the establishment of Lake Burragorang in the 20th century, but prior to this would have run into the Nepean River at Warragamba.

Archaeological evidence shows a long history of Aboriginal visitation and occupation on either side, and in the foothills, of the Blue Mountains. To the west, excavations of Noola and Capertee rockshelters undertaken in the 1960s and 1970s (Figure 1) (Hiscock and Attenbrow 2005; Johnson 1979; McCarthy 1964; Tindale 1961) were critical to the artefact typology debates of the time, and revealed people in the region from c.14.5 ka. These sites generally reflect brief, or intermittent visits, with increasing artefact numbers and technological attributes, indicative of longer occupation times, only in the last few thousand years. To the east, numerous academic and cultural heritage management (CHM) projects along the Hawkesbury-Nepean River corridor show fairly intense use of the region since c.35 ka continuing throughout the Last Glacial Maximum (LGM) and Holocene (Attenbrow 2010; Kohen et al. 1984; McDonald 2008; Nanson et al. 1987; White 2017; White and McDonald 2010; Williams et al. 2012, 2014, 2017, 2019). Excavations at Pitt Town (PT-12) and Windsor (South Bank PAD W-SP #45-5-3581) (Figure 1) suggest that the elevated terraces associated with the Hawkesbury-Nepean River were an ecological refuge through the LGM (21 ± 3 ka), with unchanging artefact attributes indicating economic and social behaviour adopted during this climatic downturn remained constant well into the Holocene period (AAJV 2017; Williams et al. 2012, 2014).

Within the Blue Mountains, archaeological investigations have largely been limited to the works of Eugene Stockton and colleagues in the 1970s. They focused on a handful of rockshelters, including Springwood Creek, King's Tableland, Wall's Cave and Lyrebird Dell (Figure 1) (Johnson 1979; Stockton 2010; Stockton and Holland 1974), which in most cases have limited chronological frameworks (reflecting the exploratory nature of the works), contain limited deposits and/or have stratigraphic complexity. Based on these constraints, only a broad view is possible, but these sites suggest initial exploration of the region only after the LGM, from ≤17.5 ka (with an earlier age of c.26.4 ka probably unrelated to the nearby material culture). The assemblages of the early deposits are rudimentary in technology, utilise (most probably) local raw material, and are characteristic of one-off, or exploratory, visits. It is only in the last few thousand years that significantly larger numbers of artefacts are recovered from these sites, and this suggests recurrent use of the region, albeit with archaeological material (and consequent population densities) generally being far less than that implied from occupation sites on the margins of the mountains (Attenbrow 2004; Johnson 1979; McDonald 2008; Stockton 2010; Stockton and Holland 1974; White and McDonald 2010; Williams et al. 2012, 2014 for further discussion on general population patterns).

Here, we present the results of a compliance-based excavation of a terminal Pleistocene deposit in Parramatta (Sydney, New South Wales), which contained an exotic raw material that was most probably sourced from west of the Blue Mountains. Through exploration of the movement of this raw material, we provide support for the Coxs River as a probable passageway through the mountains, suggest an initiation for its use, and discuss the broader implications of these findings for Aboriginal populations across the region.

Background and excavations

Parramatta CBD, in the geographic centre of Sydney, is situated on a primarily terminal Pleistocene alluvial river terrace or levee of the Parramatta River (Figure 2). While only briefly referenced in academic literature (e.g. McDonald 2008; White 2017), it is locally known to be a significant archaeological deposit. The deposit was originally discovered in 2003 as part of a CHM excavation in advance of residential development (Jo McDonald Cultural Heritage Management Pty Ltd 2005a). These excavations on the corner of George and Charles Street in the heart of the CBD uncovered a c. 1m deep sand unit, within which two phases of archaeological occupation were recovered, indicative of ephemeral Late Pleistocene visitation to the river system followed by a more systematic use and occupation of the locale in the Holocene (Jo McDonald Cultural Heritage Management Pty Ltd. 2005a, 2005b). Five radiocarbon ages were determined for materials recovered from the site, with the oldest date from below the assemblage returning an age of c. 34 ka (30,735 ± 407 BP [Wk-17435]), with the majority of the assemblage <10 ka. Since that discovery, the deposit has been the subject of over 40 compliance-based investigations a review of which is in preparation by the authors–none of which fundamentally alters these initial findings.

As part of a proposed re-development of a school precinct, we (ANW, LB) undertook a multi-phase excavation of an undeveloped part of the northern bank of Parramatta River (Figure 2). These works are some of the few investigations undertaken north of the river, and the first to identify the presence of the sand unit in this locale. Archaeological excavations initially consisted of a series of test pits (2 [L] x 1.2 [W] x 1.2 [D] m) on a grid across the school's playing fields; followed by a salvage excavation focused on a single 25m^2 locale where significant cultural material was identified within the projected development impact zone (Figure 2) (Extent Heritage 2018). The investigative test pits were dug mechanically in controlled excavation units (XU) (10 cm spits) to the underlying geological substrate (Londonderry Clay: ≤1.2m below surface). All sediment was sieved for cultural (Indigenous

Figure 2 Map of the archaeological test and open area excavations on the northern alluvial terrace of Parramatta River. Key locations are shown using centroid co-ordinates presented in MGA (Area 56). (A) The entire soil profile identified during the test excavation and revealing a thin stratum of Pleistocene alluvium (evident between c. 40 and 80cm below the surface in this example) beneath modern overburden; (B) the open area excavation, looking north and showing the location of the medium-grained porphyroblastic andalusite-cordierite hornfels (star symbol) in test pit Y1. While in the vicinity of a modern pipe, the deposits in this location where unaffected at the depths where the artefact was recovered. The original test pit is also evident as an unexcavated area in the south of the excavations; and (C) the open area excavation section, looking east, and showing the Pleistocene alluvium once the modern overburden had been removed (Scale = 20 cm).

and European) material and a range of in situ chronological samples were recovered.

The investigative phase found a pale yellowish brown (10YR 4/6) fine sandy clay unit that extended across the river terrace between c. 0.4 and 1.4 m below the surface (c. 8.05–7.05 m Australian Height Datum [AHD]; surface = 8.45m AHD). The deposit was interpreted as the terrace sand sheet, with the clay-rich composition reflective of its thinner expression here and resultant pedoturbation with the underlying geological substrate (Figure 2). Five multi-grain, single aliquot OSL ages recovered from the unit indicate initial deposition at c. 24 ka with relatively consistent formation (c. 1 cm/250 years) continuing into the mid-Holocene (Table 1, Figure 3). Despite excavations across the terrace, only a single locale (≤25m^2 in size) recovered any archaeological material (Figure 2). Specifically, some 57 stone artefacts (24/m^2) of a rudimentary technology, heavily reduced, and

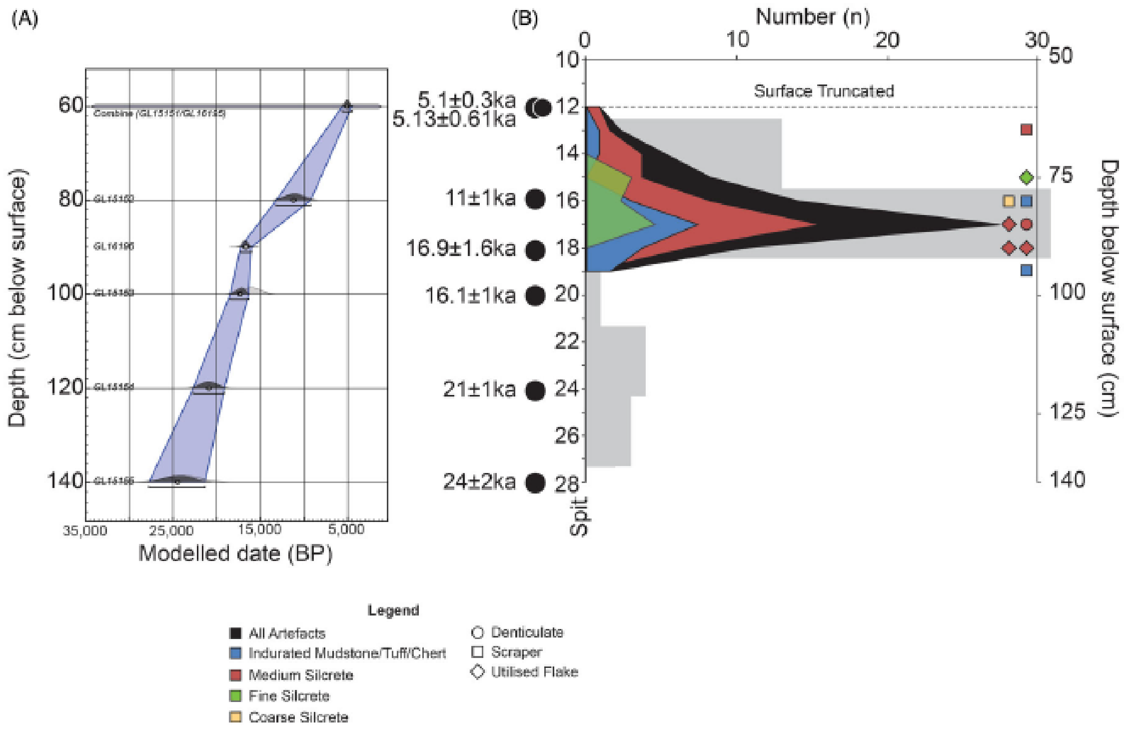

Figure 3 Summary of the archaeological material found on Parramatta River. A) An age-depth model of the OSL ages using Oxcal v4.2 and a P_Sequence deposition model (1,0, U(–2,2)) (Bronk Ramsey 2008, 2009; Bronk Ramsey and Lee 2013); and (B) number of artefacts recovered from the archaeological excavations. Total number of artefacts for the test excavation (undertaken in 20 cm XUs) are shown in grey. Artefacts from the salvage excavations (undertaken in 5 cm XUs) are shown by raw material type, with each individual tool also presented. The andalusite hornfels was recovered from XU 15, although when incorporating pedoturbation, the artefact is considered more likely to relate to the occupation event centred on XU 17, along with the remainder of the assemblage.

primarily of indurated mudstone/tuff/chert (IMTC) raw materials (77%), were located between 0.7 and 0.9 cm below surface (7.75–7.55 m AHD). A significant portion of silcrete– a raw material more broadly only minimally used until the late Holocene–was also found within the assemblage. The assemblage was centred upon an OSL age of c. 11 ka and bracketed by two ages of c. 5 and 16 ka (Table 1, Figure 3).

The salvage excavations were undertaken to further interrogate and recover the archaeological material identified within the investigative phase, which was within the project's impact footprint. These works, therefore, undertook an open area excavation 5x5m in size (Figure 2). We initially removed the modern overburden with an excavator before undertaking manual excavation of contiguous 1m^2 test pits dug in 5 cm XUs to the depths of the underlying geological substrate (Extent Heritage 2018). Excavations occurred between c. 0.45 and 1.35m below surface (c. 8.00–7.10m AHD) (Figure 3) and recovered a further 95 artefacts primarily from 0.8–0.9m below surface (7.65–7.55m AHD). Two single-grain OSL ages were recovered to validate the previous multi-grain, single-aliquot range-finding samples, and along with higher resolution recovery, showed the assemblage was probably dated to between 11 and 16 ka, with a modelled age of c. 13.9 ka (Table 1; Figure 3). Sedimentology and phytolith analysis suggest that the assemblage was deposited during an increasingly stable climate, with regular low-energy flooding of the terrace (evident by the lack of identifiable scouring events in the profile), and within mixed grass-herb-sedge vegetation.

Table 1 OSL data from investigative and salvage excavations.

				Ge γ-spectrometry (ex situ)										
Lab code	**Depth (cm beneath surface)**	**Depth (m AHD)**	**Moisture content (%)**	**K (%)**	**Th (ppm)**	**U (ppm)**	**^{226}Ra/^{238}U**	**Total Dr (Gy.ka^{-1})**	**FMM$_{\text{Min}}$ De (Gy)**	**FMM$_{\text{Max}}$ De (Gy)**	**CAM De (Gy)**	**FMM$_{\text{Min}}$ Age (ka)**	**FMM$_{\text{Min}}$ Age (ka)**	**CAM Age (ka)**
GL15151	60	7.85	8 ± 2	0.34 ± 0.04	11.04 ± 0.64	2.00 ± 0.12	1.25 ± 0.20	1.60 ± 0.09	-	-	8.2 ± 0.4	-	-	5.1 ± 0.3
GL16195	60	7.85	11 ± 3	0.20 ± 0.05	11.77 ± 0.65	2.17 ± 0.15	0.79 ± 0.10	1.48 ± 0.10	3.0 ± 0.4	5.9 ± 0.5	7.6 ± 0.8	2.04 ± 0.30	3.97 ± 0.41	5.13 ± 0.61
GL15152	80	7.65	9 ± 2	0.47 ± 0.04	11.11 ± 0.63	2.05 ± 0.12	1.22 ± 0.17	1.70 ± 0.09	-	-	18.1 ± 0.8	-	-	11 ± 1
GL16196	90	7.55	12 ± 3	0.48 ± 0.05	11.83 ± 0.66	2.05 ± 0.15	0.97 ± 0.12	1.67 ± 0.11	26.8 ± 1.2	53.5 ± 7.2	28.2 ± 1.9	16.1 ± 1.3	32.0 ± 4.8	16.9 ± 1.6
GL15153	100	7.45	10 ± 2	0.37 ± 0.04	11.58 ± 0.66	1.96 ± 0.12	1.03 ± 0.14	1.61 ± 0.09	-	-	25.7 ± 1.1	-	-	16 ± 1
GL15154	120	7.25	10 ± 2	0.31 ± 0.04	10.54 ± 0.65	1.93 ± 0.12	1.00 ± 0.14	1.47 ± 0.09	-	-	30.3 ± 1.2	-	-	21 ± 1
GL15155	140	7.05	12 ± 3	0.20 ± 0.04	10.56 ± 0.63	1.61 ± 0.11	1.08 ± 0.15	1.28 ± 0.09	-	-	30.2 ± 1.1	-	-	24 ± 2

Equivalent dose (D$_e$) values based on multi-grain, single-aliquot analysis (quartz; 125–180 µm; samples GL15151–GL15155) and single grain analysis (quartz; 180–250 µm; GL16195–GL16196), with each having a detectable natural signal (>3σ background), regenerative-dose and post-IR OSL ratios consistent with unity (0.9–1.1), and a regenerated zero dose signal not exceeding 5% of the natural signal (Duller 2003; Murray and Wintle 2000, 2003). Samples preheated to 260 °C for 10 seconds, based on dose recovery tests. Dose rate (D$_r$) values based on ex situ Ge gamma spectrometry (for γ and β D$_r$), Adamiec and Aitken's (1998) conversion factors, attenuation of present moisture content (Zimmerman 1971), current overburden and a geomagnetic latitude of 34°S (Prescott and Hutton 1994). The degree of U-Series disequilibrium was assessed by ^{226}Ra/^{238}U. Age estimates based on the CAM – Central Age Model (Galbraith et al. 1999) and, additionally for single grain measurements, the FMM$_{\text{Min}}$ – Finite Mixture Model (Minimum Population) and FMM$_{\text{Ma}}$j – Finite Mixture Model (Maximum Population) (Galbraith and Green 1990). Ages are expressed relative to their year of sampling (2015 or 2016). All uncertainties are quoted at 1r confidence and reflect combined systematic and experimental variability.

The additional artefacts recovered had similar characteristics to those in the investigative phase. A relatively large number of artefact conjoins (n=24/15%) were found within the assemblage, suggesting that this deposit reflected a short term – probably single event – camp site during which a small number of people undertook artefact production and/or retooling. From a post-depositional perspective, the conjoin analysis demonstrated that artefacts have moved laterally ≤2m, and generally ≤15 cm vertically (when removing two artefacts from the investigative phase that may have been disturbed during mechanical recovery). This suggests that even with post-depositional reworking, the assemblage was in place just prior to, or at the very onset of the Holocene.

While all of the raw materials recovered are not local to Parramatta, and suggest extensive movement from elsewhere (see also McDonald 2008; White 2017), within this assemblage there was one complete flake produced from an exotic raw material, namely a porphyroblastic medium-grained andalusite- cordierite hornfels (Figure 4).

The exotic raw material and its provenance

Andalusite-cordierite hornfels are contact metamorphic rocks, localised in occurrence and produced when a granitic magma intrudes through a shale and/or mudstone (i.e. aluminous-rich but silica-deficient protolith) – the heat from this magma converting the clay minerals present into the new metamorphic minerals andalusite (Al_2SiO_5) and cordierite ($Mg_2Al_4Si_5O_{18}$). The andalusite in this artefact is easily discernible as equant-shaped white medium-grained crystals some 3mm across, as seen clearly in Figure 4. This was confirmed by XRF analysis at ANSTO (Table 2) that shows this rock to consist predominantly of Aluminium (Al) and Silicon (Si) along with minor quantities of Magnesium (Mg) – most probably due to minor cordierite, another contact metamorphic mineral that usually occurs alongside andalusite. Compared to the analyses for pure andalusite and pure

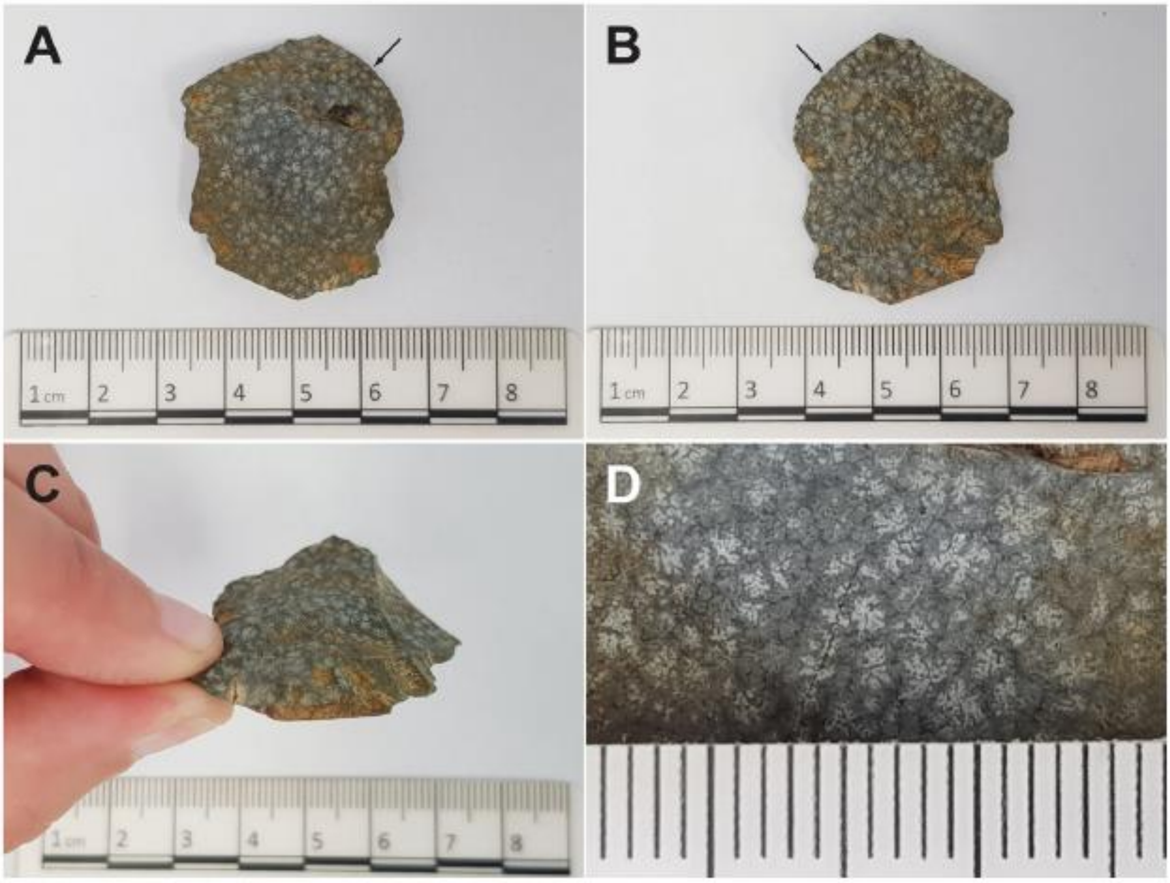

Figure 4 Photographs of the medium-grained porphyroblastic andalusite-cordierite hornfels artefact recovered: (A) ventral surface; (B) dorsal surface; (C) detail of previous flaking across the dorsal surface; and (D) detail of the surface patination. The arrows show the striking platform of the artefact.

cordierite from Deer et al. (1997a, 1997b), the andalusite-cordierite hornfels artefact has almost the same amount of Si as the cordierite analysis, but much less Mg and less Al than the pure andalusite analysis (Table 2). Additionally, as with both the andalusite and cordierite analyses of Deer et al. (1997a, 1997b), there is negligible Potassium Oxide (K_2O) and Sodium Oxide (Na_2O) in the andalusite-cordierite hornfels artefact suggesting negligible alteration to either muscovite ($KAl_2AlSi_3O_{10}(OH)_2$) or illite ($K_{0.65}Al_2Al_{0.65}Si_{3.35}O_{10}(OH)_2$) (see below for further discussion). The analyses of the artefact show that it is composed not of pure andalusite, but a mixture of predominantly andalusite with lesser cordierite and minor quartz.

Table 2 Comparison of XRF analyses of the porphyroblastic andalusite-cordierite hornfels artefact recovered from our excavations and other geological investigations, including andalusite (1 and 2) and cordierite (3) analyses from Deer et al. (1997a), and of hornfels from the Hartley region by Joplin (1968).

Oxide wt%	**O'Connell Street artefact**	**Andalusite (1)**	**Andalusite (2)**	**Cordierite (3)**	**Hartley hornfels**
SiO_2	50.50	37.44	36.70	49.95	67.00
Al_2O_3	43.40	61.46	61.85	33.95	16.34
TiO_2	0.10	0.10	0.03	0.00	0.03
Fe_2O_3	0.20	0.62	1.07	0.00	0.75
FeO	-	-	-	0.00	4.34
MgO	4.90	0.06	0.01	13.43	1.16
CaO	0.10	0.17	-	0.00	0.66
Na_2O	-	0.00	-	0.10	2.14
K_2O	0.03	0.00	-	0.00	5.44

Such hornfels are characteristic of fold mountain belts, most commonly formed when large granitic magmas intrude sedimentary sequences and convert the clay minerals within argillaceous (i.e. clay-rich) rocks such as mudstones and shales into andalusite-cordierite hornfels. The only currently documented source of these hornfels within the general region is the Lachlan Fold Belt (a fold mountain belt) to the west of the Blue Mountains (Figure 1). Although the closest source would be in the Hartley District where andalusite-cordierite hornfels have been previously described (Joplin 1935), these are much finer-grained than the raw material of the artefact, contain considerable alteration of the andalusite and cordierite to fine-grained white micas, and have a very different chemistry. The analyses of the porphyroblastic andalusite-cordierite artefact in no way matches that of Joplin's (1968) analysis of an andalusite-cordierite hornfels from Hartley, which has much higher Si, Na and K, considerably more Fe, and much less Al and Mg (Table 2).

Although we have conducted extensive literature reviews on andalusite-cordierite hornfels occurrences to the west, northwest and southwest of the Blue Mountains, we have not found any descriptions of any medium-grained porphyroblastic andalusite-cordierite hornfels. The closest possible site would be in the Megalong Valley situated c. 75 km from the study area, and in the Coxs River corridor, since the river runs through the Megalong Valley, and fluvially transports underlying geological materials. Importantly, although the Hartley District is the best documented and closest location for in situ outcropping andalusite-cordierite hornfels, granites of the Late Carboniferous the

Bathurst Batholith intrude through Devonian metasedimentary sequences (including claystones) of the Lambie Group further to the south, along both the Megalong Valley and Coxs River corridor making this proposed source area for our artefact even more likely (Bryan 1966).

Although various rock-types occur within diatremes (explosive volcanic necks) within the Sydney Basin, no such andalusite-cordierite hornfels have ever been recorded, which excludes these as a possible local source. This is because these diatremes and associated dykes would not have had enough latent heat of intrusion to result in a significant effect on the surrounding country rocks (see below). Further, most of these have intruded through the Hawkesbury Sandstone, which, due to its high quartz content, when metamorphosed would not lead to the formation of an andalusite hornfels. Even for the largest igneous intrusion in the Sydney area, the Jurassic aged Prospect sill – over 200m thick – Wiltshire (1958) only mentioned the occurrence of microscopic altered prismatic andalusite, presumably sub millimetre in size. Additionally, although he conducted X-ray diffraction analysis of the hornfels, he did not find any trace of andalusite in these analyses and concluded that the original andalusite had been replaced by illite/muscovite. Thus, based on the published literature, our medium-grained porphyroblastic andalusite-cordierite hornfels was most probably sourced to the west of the Blue Mountains, with the probable location as the Coxs River area being in closest proximity to the Bathurst Batholith contact aureole.

Another possibility is that the source cobble for the andalusite-cordierite hornfels came from one of the Quaternary gravels from western Sydney as described by Smith and Clark (1991). However, their descriptions of both the Cranebrook Formation and Rickabys Creek Gravel only say rounded to well-rounded hornfels and do not give any further information. We assume that this is because these are all fine-grained and hence not coarse enough to merit further details. Additionally, Hatherly (2020) in his description of the Rickabys Creek Gravel describes it as a Palaeogene to Neogene polymictic basal unit of the alluvial Londonderry Terrace comprising pebble to cobble-sized clasts of quartzite and hornfels that were transported down the palaeo-Wollondilly and Hawkesbury-Nepean river systems. Once again, he gives no detailed description of the hornfels, suggesting that they are fine-grained and largely nondescript compared to our andalusite-cordierite hornfels artefact. Thus, based on the published literature, no similar porphyroblastic andalusite-cordierite hornfels are known from the Quaternary gravels of the western Sydney region.

Finally, an argument can be made that the porphyroblastic andalusite-cordierite hornfels artefact could have been recovered closer to Parramatta, since the Coxs River is a tributary of the Hawkesbury-Nepean River, and so it could have been fluvially transported to the eastern side of the Blue Mountains. However, this distinct raw material has not been previously documented in any excavated archaeological sites across the Cumberland Plain – one of the most intensely archaeologically investigated areas in Australia – nor in the extensive Pleistocene and Holocene records from the banks of the Hawkesbury-Nepean River itself (e.g. AAJV 2017; Attenbrow 2010; McDonald 2008; White 2017; White and McDonald 2010; Williams et al. 2012, 2014, 2017). Long-distance trade between Aboriginal groups is similarly unlikely to provide a plausible mechanism, with populations generally too low at this time for such networks (c. 1/120 km^2) (Williams 2013; Williams et al. 2015); and current archaeological evidence suggesting such interactions were largely late Holocene in origin (e.g. McBryde 1987; Smith 2013; Smith and Veth 2004). It is, therefore, considered more likely that the exotic raw material was collected by people either from the Megalong Valley itself, or along the Coxs River, before being carried to Parramatta.

Results and discussion

Compliance based archaeological excavations on the northern bank of Parramatta River identified the presence of a small Aboriginal group, probably a hunting and/or gathering band, visiting the area in the terminal Pleistocene (between 11 and 16 ka, and centred on c. 13.9 ka). The recovered assemblage is indicative of a one-off visitation to the locale. An exotic raw material, a medium-grained porphyroblastic andalusite-cordierite hornfels, within the assemblage has its closest natural occurrence in the Megalong Valley, west of the Blue Mountains. This finding strongly suggests that the same hunter-gatherer population was utilising – or at least exploring – both sides of the Blue Mountains in the terminal Pleistocene, with the Coxs River corridor forming the most probable inter-connecting passage between the two regions. While we cannot be certain that this corridor was used, hornfels are found in fluvial deposits along this route, and from where the artefact may have been collected. Further, this route between Parramatta and the Megalong Valley is only a distance of c. 76 km, with potential alternative routes to avoid the mountains requiring significant distances to be covered (c. 350km to the south via Goulburn, or c. 500 km to the north via Merriwa). Based on our findings, it is therefore probable that Aboriginal populations would have used this corridor, and have been traversing the mountains for some 14,000 years prior to European contact.

The initiation of the Coxs River corridor at c.14 ka aligns well with other nearby archaeological sites within the mountains (Stockton 2010; Stockton and Holland 1974), all of which are dated to the terminal Pleistocene or later, and most of which would have been accessible via this same river system. Currently, a disputed post-LGM age of ≤17.5ka is the earliest evidence for people in the Blue Mountains and adds to the argument that these upland regions were not visited earlier in the Pleistocene. A similar initiation timing of c. 14 ka has recently been reported in the Australian Alps to the south (e.g. Theden-Ringl and Langley 2018). It is probable that prior to, and during, the LGM these ranges formed a significant, albeit intermittent, barrier extending for several hundred kilometres across southeast Australia; and influenced the movement of early peoples by funnelling them north-south along the continental shelf, rather than inland. Such a finding may have implications for the broader story of the peopling of eastern Australia. Certainly, genomic research has shown that founding populations travelled down the coastal fringe of eastern Australia (Tobler et al. 2017), and it would be interesting to understand what role the barrier played in these migration patterns.

Palynology from the Penrith Lakes – an abandoned meander on the floodplain of the Hawkesbury-Nepean River prior to quarrying – by Chalson and Martin (2008) suggests that the LGM vegetation was predominantly shrubland/grassland with very low representation of trees and other plants common on the floodplain today. Palynology also suggests that it is probable that shrublands dominated the Blue Mountains during the LGM and terminal Pleistocene (e.g. Robbie and Martin 2007), although Eucalyptus-dominated refugia may have been confined to small patches where conditions favoured their survival and this might have included river valleys like the Coxs River. The post-LGM recovery of vegetation communities in the broader landscape is likely to have occurred in the region after 15 ka (Mooney et al. 2017) and tree cover increased rapidly after 12 ka (Dodson 1998). This post-LGM recovery fits well with the timing of the movement of this exotic material. Further, this timing is also coincident with considerable climatic and environmental change, including the onset of rapid sea-level rise from Meltwater Pulse 1A (c.14.7–13.5 ka), during which time significant tracts of the coastal shelf were lost and/or disrupted (Williams et al. 2018), and with the Antarctic Cold Reversal (ACR, from c. 14.5–12.5 ka) that arguably resulted in colder and probably wetter conditions (Fletcher and Moreno 2011).

The delayed use of the uplands after the LGM some 4,000–7,000 years after the height of this climatic disruption, and at least 1,000–4,000 years after a continental population nadir responding to the same event (Williams 2013) further suggests either a significant period of time was needed for environmental stabilisation of the region to be useful for resource exploitation and/or for socio-economic reasons to prompt populations to explore them. Data from PT-12 suggests that ‘refuge-like’ behaviours – evident by an unchanging artefactual assemblage either compositionally or technologically – appeared to continue well into the terminal Pleistocene (Williams et al. 2014), with populations tethered to large water courses, and much of the surrounding marginal country remaining unused (see also McDonald 2008). This perhaps implies that hunter-gatherer societies took a significant time to recover from the LGM. We acknowledge that recent work by White (2017) in disentangling unstratified sites is beginning to revisit the pre-Bondaian model of activity across the Cumberland Plain. However, even this comprehensive study has only identified an extremely low number of sites that may extend into this period, and with the exception of those discussed here, none has a chronology suggesting use in the immediate post-LGM period. The exploration of, and transition through the uplands can perhaps then be considered the first evidence of these social, environmental and economic conditions changing, and a re-exploration and/or expansion of populations into more marginal or recovering resource areas following the LGM.

The exploration of the uplands may therefore reflect a determined effort to find new ecological niches following increased demographic pressures on local littoral resources. Even then, however, it appears that there is little evidence for extended periods of occupation within the mountains, and that any attempts for opening up these regions to longer residence times proved fruitless. The appearance of a number of sites to the west of the mountains at a similar time (including Noola and Capertee) may suggest that such exploration continued well beyond the upland region, or potentially from other directions. Acknowledging the limitations in the Blue Mountains data, this conforms well with more recent systematic studies in similar upland environments (e.g. Theden-Ringl 2016, 2017; Theden-Ringl and Langley 2018), that show occupation around the margins of the Great Dividing Range with only occasional short-term visits into the uplands at optimal environmental conditions.

Finally, our findings provide some guide to the size of the ranging territories of hunter gatherers in temperate regions during the terminal Pleistocene. When considering the distances of cultural deposits at PT-12 and at Windsor, some 90 km from the mouth of the Hawkesbury-Nepean River (and the probable entry point into the Sydney Basin hinterland), and the distances between Parramatta and Megalong Valley (c. 75 km), it suggests populations were utilising some 8,000 km^2 (90x90 km) during this time. This is an unsophisticated approximation, but it nonetheless provides a baseline for future estimates, for example, to consider the increasing disparity between genomic and archaeological studies. In this example, genomic work implies that populations were relatively sedentary by c. 40 ka (Tobler et al. 2017), while archaeological evidence suggests a more complex history of movement and landscape use throughout the last 50,000 years (e.g. Hiscock and Wallis 2005; Smith 2013; Veth 1993; Williams et al. 2013). It is clear that both the archaeological and genetic literature are using terms such as ‘mobility’, ‘territory’, and ‘sedentism’ at a very general and qualitative level. As such, some of the disparity between the disciplines may simply be interpretations of what is meant by these terms. Beginning to quantitatively define ranging territories, and what is meant by ‘regional nomadism’ (Tobler et al. 2017), is therefore becoming essential.

In conclusion, archaeological excavations on the banks of the Parramatta River have provided a unique opportunity to explore the movement of Aboriginal people across the Blue Mountains during the terminal Pleistocene. Acknowledging that there is a lack of available data on the broader distribution of hornfels, and that there has been no comprehensive study of the past occupation of the Blue Mountains, based on current available evidence a number of findings can be hypothesised. Specifically, we contend that the finding of an exotic raw material sourced from west of, or within, the uplands provides strong support that hunter-gatherers were successfully traversing the mountains for some 14,000 years prior to the arrival of Europeans in the late 18th century. Along with other regional data, this hypothesis suggests that the uplands in southeast Australia were only explored by Aboriginal populations after the LGM, and that they may have formed a considerable barrier to the initial peopling and settlement of Sahul earlier in the Pleistocene. Exploration of the uplands after the LGM appeared to have been somewhat delayed and suggests that certain environmental and/or socioeconomic conditions needed to be met before they became of interest to hunter-gatherers. Timing of this is variable, but our data place this date late in the terminal Pleistocene (<14 ka). While there is currently no direct evidence, the loss of the productive littoral shelf at this time due to rapidly rising sea-level or an increased supply of moisture associated with the ACR may have been, at least in part, a contributing factor. Finally, our results provide an initial indication of the quantitative size of the ranging territories for hunter-gatherer populations within temperate southeastern Australia. This provides a first coarse attempt at defining the nature of 'regional nomadism', which is becoming an increasingly divergent term between archaeological and genomic studies, and which desperately requires resolution to facilitate the merging of the two disciplines.

Our findings, while speculative in some areas, do prompt several future lines of enquiry. These include the need to revisit existing archaeological assemblages from the Cumberland Plain to identify whether similar types of exotic raw material have been found previously, but not documented as such. It would not be uncommon for volcanically-derived materials to be listed by archaeologists under generic terms, with a research focus historically on IMTC and silcrete exploitation. Along with the recent study by White (2017) showing an increasingly >5ka signal within Cumberland Plain assemblages, identification and sourcing of exotic raw materials may provide an improved understanding and/or refinement of movement and behaviour of Pleistocene and early Holocene populations across the region. Tracing such material is essential in allowing a more robust consideration of the movement and ranging extents of Pleistocene populations to be calculated. It is also clear that our understanding of the use of the uplands west of Sydney remains poor. With the exception of some exploratory investigations in the 1970s, there has been little systematic study of the region. While the model proposed above aligns well with more extensive studies of the Great Dividing Range further south (e.g. Theden-Ringl 2016, 2017), it is nonetheless desirable to implement the same level of investigation west of Sydney to ensure the same findings hold. Given that some of the earliest archaeological evidence in the region come from open sites (e.g. PT-12, Cranebrook Terrace), similar environments, along with closed or rockshelter sites, should also form a focus of any regional upland studies.

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References

AAJV (Austral – Extent Heritage Joint Venture) 2017 Windsor Bridge Replacement Project – Aboriginal Archaeological Excavation Report. Unpublished Report prepared for NSW Roads and Maritime Services. Retrieved 14 September 2020 from http://www.rms.nsw.gov.au/projects/sydney-west/windsor-bridgereplacement/project-documents.html

Adamiec, G. and M.J. Aitken 1998 Dose-rate conversion factors: update. *Ancient TL* 16(2):37–50.

Attenbrow, V. 2004 *What's Changing: Population Size or Land-Use Patterns? The Archaeology of Upper Mangrove Creek, Sydney Basin*. Terra Australis 21. Canberra: ANU E Press.

Attenbrow, V. 2010 *Sydney's Aboriginal Past: Investigating Archaeological and Historical Records*. 2nd ed. Sydney: University of New South Wales Press.

Barrallier, F. 1802 [1975] *Journal of the Expedition into the Interior of New South Wales 1802. By Order of His Excellency Governor Gidley King*. Melbourne: Marsh Walsh Publishing.

Blaxland, G. 1813 [1913] *A Journal of a tour of discovery across the Blue Mountains, New South Wales, in the year 1813*. Sydney, NSW: Australian Historical Society.

Bronk Ramsey, C. 2008 Deposition models for chronological records. *Quaternary Science Reviews* 27(1–2): 42–60.

Bronk Ramsey, C. 2009 Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337–360.

Bronk Ramsey, C. and S. Lee 2013 Recent and planned developments of the program OxCal. *Radiocarbon* 55(3–4):720–730.

Bryan, J.H. 1966 *Sydney Geological Sheet SI/56-05*. 3rd ed. Sydney: Geological Survey of New South Wales.

Chalson, J.M. and H.A. Martin 2008 A 38,000 year history of the vegetation at Penrith Lakes, New South Wales. *Proceedings of the Linnean Society of New South Wales* 129:97–111.

Cunningham, C. 1996 *Blue Mountains Rediscovered: Beyond the Myths of Early Australian Exploration*. Kenthurst, NSW: Kangaroo Press.

Deer, W.A., R.A. Howie and J. Zussman 1997a. *Rock-Forming Minerals. Volume 1A: Orthosilicates*. 2nd ed. London: The Geological Society.

Deer, W.A., R.A. Howie, and J. Zussman 1997b. *Rock-Forming Minerals. Volume 1B: Disilicates and Ring Silicates*. 2nd ed. London: The Geological Society.

Dodson, J.R. 1998 Timing and response of vegetation change to Milankovitch forcing in temperate Australia and New Zealand. *Global and Planetary Change* 19: 161–174.

Duller, G.A.T. 2003 Distinguishing quartz and feldspar in single grain luminescence measurements. *Radiation Measurements* 37(2):161–165.

Extent Heritage 2018 O'Connell Street Public School (Old Kings School), Parramatta, NSW. Unpublished report prepared for Tonkin Zulaikha Greer Architects and NSW Department of Education.

Fletcher, M.-S. and P.I. Moreno 2011 Zonally symmetric changes in the strength and position of the Southern Westerlies drove atmospheric CO2 variations over the past 14 k.y. *Geology* 39(5):419–422.

Galbraith, R.F. and P.F. Green 1990 Estimating the component ages in a finite mixture. *Nuclear Tracks and Radiation Measurements* 17:196–206.

Galbraith, R.F. R.G. Roberts, G.M. Laslett, H. Yoshida and J.M. Olley 1999 Optical dating of single and multiple grains of quartz from Jinmium rock shelter (northern Australia): Part I, Experimental design and statistical models. *Archaeometry* 41(2):339–364.

Hatherly, P.J. 2020 Landscape evolution of the Blue Mountains revealed by longitudinal river profiles and Cenozoic basalts and gravels. *Australian Journal of Earth Sciences* 67(2):243–263.

Herbert, C. and R. Helby 1980 *A Guide to the Sydney Basin*. Geological Survey of New South Wales Bulletin 26, NSW Department of Mineral Resources.

Hiscock, P. and V. Attenbrow 2005 *Australia's Eastern Regional Sequence Revisited: Technology and Change at Capertee 3*. BAR International Series 1397. Oxford: Archaeopress.

Hiscock, P. and L. Wallis 2005 Pleistocene settlement of deserts from an Australian perspective. In P. Veth, M.A. Smith and P. Hiscock (eds), *Desert Peoples: Archaeological Perspectives*, pp.34–57. Melbourne: Blackwell Publishing.

Jo McDonald Cultural Heritage Management Pty Ltd. 2005a Archaeological salvage excavation of site CG1 (NPWS* 45-5-2648) at the Corner of Charles and George Streets, Parramatta, NSW. Unpublished report prepared for Meriton Apartments Pty Ltd.

Jo McDonald Cultural Heritage Management Pty Ltd. 2005b Archaeological salvage excavation of site RTAG1, 109-113 George Street, Parramatta, NSW. Unpublished report prepared for Landcom.

Johnson, I. 1979 The Getting of Data: A Case Study from the Recent Industries of Australia. Unpublished PhD Thesis, The Australian National University, Canberra, ACT.

Joplin, G.A. 1935 The petrology of the Hartley District. Iii The contact metamorphism of the Upper Devonian (Lambian) series. *Proceedings of the Linnean Society of New South Wales* 60:16–50.

Joplin, G.A. 1968 *A Petrography of Australian Metamorphic Rocks*. Sydney: Angus and Robertson.

Kohen, J.L., E.D. Stockton and M.A.J. Williams 1984 Shaws Creek KII Rockshelter: A prehistoric occupation site in the Blue Mountains piedmont, eastern New South Wales. *Archaeology in Oceania* 19(2):57–73.

McBryde, I. 1987 Goods from another country: Exchange networks and the people of the Lake Eyre basin. In D. J. Mulvaney and J. P. White (eds) *Australians to 1788*, pp.253–273. Broadway, New South Wales: Fairfax, Syme and Weldon Associates.

McCarthy, F.D. 1964 The archaeology of the Capertree Valley. New South Wales. *Records of the Australian Museum* 26(6):197–246.

McDonald, J. 2008 *Dreamtime Superhighway – Sydney Basin Rock Art and Prehistoric Information Exchange*. Terra Australis 27. Canberra: ANU E Press.

Mooney, S.D., K. Sniderman, A.P. Kershaw, S.G. Haberle and J. Roe 2017 Quaternary vegetation in Australia. In D. Keith (ed.) *Australian Vegetation*, pp.63–88. Cambridge: Cambridge University Press.

Murray, A.S. and A.G. Wintle 2000 Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements* 32(1): 57–73.

Murray, A.S. and A.G. Wintle 2003 The single aliquot regenerative dose protocol: Potential for improvements in reliability. *Radiation Measurements* 37(4–5):377–381.

Nanson, G.C., R.W. Young and E.D. Stockton 1987 Chronology and palaeoenvironment of the Cranebrook Terrace, near Sydney, containing artefacts more than 40,000 years old. *Archaeology in Oceania* 22(2):72–78.

Prescott, J.R. and J.T. Hutton 1994 Cosmic ray contributions to dose rates for luminescence and ESR dating: Large depths and long-term time variations. *Radiation Measurements* 23(2–3):497–500.

Robbie, A. and H.A. Martin 2007 The history of the vegetation

from the last glacial maximum at Mountain Lagoon, Blue Mountains, New South Wales. *Proceedings of the Linnean Society of New South Wales* 128:57–80.

Smith, J. 2009 New insights into Gundungarra place naming. In H. Koch and L. Hercus (eds) *Aboriginal Placenames – Naming and Re-naming the Australian Landscape*, pp.87–114. Canberra: University Printing Press ANU.

Smith, M.A. 2013 *The Archaeology of Australia's Deserts*. New York: Cambridge University Press.

Smith, V. and N.R. Clark 1991 *Geology of the Penrith 1: 100 000 Sheet*. Sydney: Geological Survey of New South Wales.

Smith, M.A. and P.M. Veth 2004 Radiocarbon dates for Baler shell in the Great Sandy Desert. *Australian Archaeology* 58(1):37–38.

Stockton, E.D. 2010 Review of early Bondaian dates. *Mankind* 11(1):48–51.

Stockton, E.D. and W. Holland 1974 Cultural sites and their environment in the Blue Mountains. *Archaeology and Physical Anthropology in Oceania* 9(1):36–65.

Theden-Ringl, F. 2016 Aboriginal presence in the high country: New dates from the Namadgi Ranges in the Australian Capital Territory. *Australian Archaeology* 82(1):25–42.

Theden-Ringl, F. 2017 A reassessment of technological change models for the Australian high country. *Archaeology in Oceania* 52(2):81–97.

Theden-Ringl, F. and M.C. Langley 2018 At the margins of the high country: A terminal Pleistocene to late Holocene occupation record from Wee Jasper, southeastern Australia. *Australian Archaeology* 84(2): 145–163.

Tindale, N.B. 1961 *Archaeological Excavation of Noola Rock Shelter: A Preliminary Report*. South Africa: Government Printer.

Tobler, R., A. Rohrlach, J. Soubrier, P. Bover, B. Llamas, J. Tuke, N. Bean, A. Abdullah-Highfold, S. Agius, A. O'Donoghue, I. O'Loughlin, P. Sutton, F. Zilio, K. Walshe, A.N. Williams, C.S.M. Turney, M. Williams, S.M. Richards, R.J. Mitchell, E. Kowal, J.R. Stephen, L. Williams, W. Haak and A. Cooper 2017 Aboriginal mitogenomes reveal 50,000 years of regionalism in Australia. *Nature* 544(7649):180–184.

Veth, P.M. 1993 *Islands in the Interior: The Dynamics of Prehistoric Adaptations within the Arid Zone of Australia*. International Monographs in Prehistory. Michigan: Ann Arbor.

White, B. 2017 Analysis with confidence: Distinguishing pre-Bondaian and Bondaian silicified mudstone artefact assemblages from the Cumberland Plain of Western Sydney. *Australian Archaeology* 83(3):143–161.

White, B., and J. McDonald 2010 Lithic artefact distribution in the Rouse Hill Development Area, Cumberland Plain. *Australian Archaeology* 70(1):29–38.

Williams, A.N. 2013 A new population curve for prehistoric Australia. *Proceedings of the Royal Society B: Biological Sciences* 280(1761):20130486

Williams, A.N., F. Atkinson, M. Lau and P. Toms 2014 A Glacial cryptic refuge in southeast Australia: Human occupation and mobility from 36,000 years ago in the Sydney Basin. *Journal of Quaternary Science* 29(8): 735–748.

Williams, A.N., A. Burrow, P. Toms, O. Brown, M. Richards and T. Bryant 2017 The Cranebrook Terrace revisited: Recent excavations of an early Holocene alluvial deposit on the banks of the Nepean River, NSW, and their implications for future work in the region. *Australian Archaeology* 83(3):100–109.

Williams, A.N., P. Mitchell, R.V.S. Wright and P. Toms 2012 A Terminal Pleistocene open site on the Hawkesbury River, Pitt Town, NSW. *Australian Archaeology* 74(1):85–97.

Williams, A.N., P.S. Toms, D. Marcus, A. Yousif, J. McGuinness, A. O'Sullivan, L. Barry, T. Bryant and J.C. Wood 2019 The first successful application of Optically Stimulated Luminescence dating to a colonial era (<0.25ka) archaeological site in Australia. *Journal of Archaeological Science: Reports* 24:9931002.

Williams, A.N., S. Ulm, A.R. Cook, M. Langley and M.

Collard 2013 Human refugia in Australia during the Last Glacial Maximum and Terminal Pleistocene: A geo-spatial analysis of the 25-12ka Australian archaeological record. *Journal of Archaeological Science* 40(12): 4612–4625.

Williams, A.N., S. Ulm, T. Sapienza, S. Lewis and C.S.M. Turney 2018 Sea-level change and demography during the Last Glacial Termination and early Holocene across the Australian continent. *Quaternary Science Reviews* 182:144–154.

Williams, A. N., S. Ulm, C.S.M. Turney, D. Rohde and G. White 2015 Holocene demographic changes and the emergence of complex societies in Prehistoric Australia. *PLoS One* 10(6):e0128661.

Wiltshire, H.G. 1958 Contact metamorphism adjacent to a teschenite intrusion. *Journal of the Geological Society of Australia* 6(1):11–20.

Zimmerman, D.W. 1971 Thermo-luminescent dating using fine grains from pottery. *Archaeometry* 13(1): 29–52.