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A Glacial cryptic refuge in southeast Australia: Human occupation and mobility from 36,000 years ago in the Sydney Basin, New South Wales.

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Abstract

Excavations across a source-bordering dune overlooking the Hawkesbury River suggest an initial occupation of the region by at least 36ka, with variable but uninterrupted use until the early Holocene; following abandonment, the site was then re-occupied by ~3ka. Along with a handful of other sites, the results provide the earliest reliable evidence of permanent regional populations within southeastern Australia, and support a model in which early colonisers followed the coastal fringe with forays along the main river systems. The evidence is consistent with Williams' (2013) demographic model, which suggested low, but established regional populations prior to the Last Glacial Maximum (LGM), a population nadir following the LGM, and increasing use of the region from ~12-8ka. The site exhibits increased use at the onset and peak of the LGM, and provides an example of a cryptic refuge as defined by Smith (2013). Specifically, changing artefact densities and attributes show the site was used repeatedly, but for shorter periods through this time, and suggest it formed one of a series of key localities in a point-to-point (rather than home-base) subsistence strategy. This strategy was maintained until the site's abandonment in the early Holocene, despite changing population and climatic conditions through the Terminal Pleistocene. The findings here demonstrate the importance of the Hawkesbury River as a resource area for the early occupation and survival of Aboriginal people over the last 46,000 years; and highlight its importance as a focus for future research.

Keywords

Early Aboriginal occupation, Last Glacial Maximum, cryptic refuge, Hawkesbury River, demography

1. Introduction

The colonisation date of Australia is now conservatively established at least 46ka and possibly earlier (O'Connell and Allen, 2012; Roberts et al., 1990). There are several archaeological sites across the top end of Australia that had been occupied by this time, including Carpenters Gap 1, Narwarla Gabarnmang, Malakunanja, Nauwalabila and Riwi (Balme, 2000; David et al., 2011; O'Connor, 1995; Roberts et al., 1994). Exploration of the continent by founding populations occurred quickly with evidence of human activity in the southernmost parts of Australia by 40ka (e.g. Turney et al., 2001). This first long phase (46-30ka) was brought to an end by climatic conditions during the Last Glacial Maximum (LGM) and although occupation persisted in many regions, evidence is sparse and populations may not have grown and consolidated again until the start of the Holocene (Williams, 2013). It is not until after the LGM that archaeological materials (*a priori* population) increase (e.g. Hiscock, 2008; Smith, 2013). However, our understanding of when parts of Australia were 'permanently' occupied, or and the nature and mechanism of population movement across the country is still poor.

Recently Williams et al. (2013) identified the Sydney Basin bioregion as a possible refugium during and prior to the LGM, and a location in which early colonisation links between the north and south of Australia may be found. However, despite over 50 years of research within the Sydney Basin, evidence for pre-LGM and LGM occupation has been elusive. Overwhelmingly, sites appear to be of (usually late) Holocene age, with only five archaeological sites showing evidence earlier than this: Cranebrook Terrace containing artefacts dated to ~40ka (Nanson et al., 1987); Bass Point midden with a basal deposit dated to ~17.5-7.7ka (Hughes and Djohadze, 1980); SGCD16 (Fal Brook Site), a shallow open site with artefacts recovered in association with charcoal dated to ~34ka (Koettig, 1987); Shaws Creek KII rockshelter, which has basal ages of ~16ka (Kohen et al., 1984); RTA-G1, a sand deposit adjacent the Parramatta River with a basal age of ~32ka (McDonald, 2008); and the current site, PT 12 (Williams et al., 2012). Of these, several have significant credibility issues either due to dating unsecure materials, or reproducibility.

In this paper, we present the results of compliance-based archaeological excavations on a ridgeline overlooking the Hawkesbury River in northwest Sydney. Using results previously published in Williams et al. (2012) and two new large-scale excavations, we demonstrate ongoing occupation of the region between 36 and 8ka, and discuss the site's contribution to an understanding of the colonisation patterns of Australia, and the nature of occupation during periods of significant climatic deterioration.

2. Study Area

Between 2008-2013, Archaeological and Heritage Management Solutions Pty Ltd undertook archaeological investigations of a large sand body, PT 12 (#45-5-3198), in Pitt Town, northwest

Sydney, in advance of development. PT 12 sand body is situated on the edge of a ridge line that follows the Hawkesbury River and associated tributaries. Preliminary findings have been presented in Williams et al. (2012), and here we provide results on two further excavations located within PT 12 to the south (PT 12-A) and east (PT 12-B) of the original works (Figure 1).

The focus of this paper is on the works undertaken at PT 12-A, which consisted of a large salvage excavation totalling 100m^2 in two locations on the sand body. These two locations were selected through the findings of geo-physical and gridded test excavations, and consisted of: (1) a shallow part of the deposit 300 m from the edge of the ridge (of which 25m^2 was excavated) (MGA 56 301237.81E, 6282132.28N) (Figure 2); and (2) the deepest part of the sand body on the crest of the ridge overlooking the river (of which 75m^2 was excavated) (MGA 56 301196.51E, 6282076.27N) (Figure 3). All excavation was done by hand using 5 cm spits in contiguous 50 cm squares; all material was wet sieved through a 3mm mesh. Soil and dating samples were recovered from the sections of the completed excavations. Excavation continued until sterile deposit or the water-table was reached, which varied between 110 and 250 cm below the surface. Further discussion on the excavations can be found in AHMS (2012).

At PT 12-B, AHMS undertook test excavations in the form of a grid of 1 m^2 test pits distributed across a ridge, back dunes and swales, slopes and alluvial flats adjacent to the river. All excavation was done by hand using 10 cm spits in contiguous 50 cm squares; all material was wet-sieved through a 5mm mesh. Soil and dating samples were recovered from the sections of the completed excavations. Excavation continued until sterile deposit was reached at ~120 cm below the surface. The test pits identified a continuation of the sand body along the entire ridgeline, and several foci of occupation. Here, we only discuss two test pits in detail, namely pits 56 (MGA 56 302694.20E, 6283447.11N) and 89 (MGA 56 302494.17E, 6283547.22N), within which significant archaeological material was recovered. Further discussion on the excavations can be found in AHMS (2011).

3. The Excavations

3.1 Sedimentology and Artefact Deposition

Williams et al. (2012) identified the sand body as a Kandosol soil profile (Isbell 2002) consisting of a 1 m deep fine to medium loamy sand with various inclusions and levels of bioturbation, overlying Pitt Town Sands or Londonderry Clay (both considered to pre-date the Aboriginal colonisation of Australia). The upper profile (<50cm) revealed extensive disturbance from past agricultural use, with levels of bioturbation decreasing with depth. Archaeological material was generally found in the main orange loamy sand unit beneath the topsoil at depths ranging between 35 and 100 cm below the surface (Figure 4). The profile was largely homogenous, with no evidence of former land-surfaces or other bedding. As a result, there was no clear indication of how the sand body formed (either via fluvial or aeolian processes) nor how the included artefacts were deposited (i.e. were they *in situ* or moved through vertical displacement from the surface).

Works at both PT 12-A and –B demonstrate that Williams et al.'s description is consistent across the sand body, with some minor local variation. This is most evident in relation to depth, which ranges from <90 cm to >250 cm; and colour, which can range from white (Figure 2) through to deep red brown (Figure 3). The presence of ironstone nodules in places reflects either shallower parts of the sand body or a higher watertable (Figure 2), and does not necessarily represent culturally sterile Pitt Town Sands as previously thought.

Additional particle size and thin section information shows that the sand unit was deposited in glacial arid conditions in Marine Isotope Stage (MIS) 6 (190-130ka). The high proportion of medium, coarse and very coarse sand makes fluvial deposition the most likely explanation (Figure 5). However, since Aboriginal colonisation, there is evidence of increasing fine materials in the profile, most notably through the section corresponding to MIS 2 and 3, indicating that aeolian processes later came to dominate. This is supported by the results of the investigations at PT12-B, that found swales and smaller back-dunes extending several hundred metres from the ridge's edge, demonstrating that PT 12 was part of a larger dune field; several parts of which appear to have formed only in the last 30ka (Figure 5).

These results reflect a highly active landscape in which wind-blown deposits continuously exposed and buried land surfaces, especially during Aboriginal occupation of the region. We therefore believe that archaeological materials could quite easily have been deposited on these temporary land surfaces and then been relatively quickly buried, with little other evidence of the former surface. Opportunistic conjoin analysis also indicated that movement of the majority of the artefactual material was generally less than 10 cm through the profile, and sections of individual heat-fractured cobbles were frequently found in close association (at PT 12-A). Vertical displacement from the surface (of the entire assemblage at least) is considered an unlikely alternative given the amount of conjoins present, combined with the tightly constrained chronology.

3.2 Chronology

In combination with Williams et al. (2012), 25 Optically Stimulated Luminescence ages and one radiocarbon age have been obtained from the sand body, making it one of the most comprehensively dated archaeological sites in the Sydney Basin (Tables 1 and 2; Figure 4). OSL samples were prepared using standard procedures by the University of Gloucestershire. Dose equivalent to the natural luminescence signal was estimated through the Single-Aliquot Regenerative-dose (SAR) protocol (Murray and Wintle, 2000, 2003) using 12 multigrain 8 mm aliquots. For each sample, Dose Recovery, Low and High Repeat-Regenerative doses, post-IR OSL (Duller 2003) and partial resetting of OSL prior to burial (Bailey et al. 2003) were assessed. The rate of dose exposure was assessed from each sample's radiochemistry (Adamiec and Aitken 1998) using a laboratory-based Ortec GEM-S high purity Ge coaxial detector system, accounting for modulation forced by grain size (Mejdahl 1979) and present moisture content (Zimmerman 1971). Cosmogenic Dr values were calculated on the basis of sample depth, geographical position and matrix density (Prescott and Hutton 1994)..

Of the 25 OSL ages, eight were considered to have analytical caveats (including partial bleaching, over dispersion, feldspar contamination and/or a failed dose recovery test), and as such must be treated with greater caution. The majority of these samples came from depths well beneath the archaeological assemblage (e.g. GL11080) and are largely irrelevant to our analysis. A small number of them came from the upper deposits (characterised by a heavily mixed plough soil), and we similarly treat these ages with circumspection. The laboratory only identified one age that should be rejected outright, GL10009 (see Williams et al., 2012 for further discussion).

The OSL chronology indicates that the lowest deposits of the PT 12 sand body generally dated to >90ka, with the oldest age of ~143ka found at 250 cm below the surface in PT 12-A(2). The lower deposits at PT 12-B were all dated to 36-30ka, and suggest some parts of the sand body formed later than others. The lowest archaeological materials were associated with ages between ~63-51ka, although the small number of artefacts at these depths probably indicate some minor vertical displacement to these depths rather than *in situ* deposition (Figure 6). The lowest peak in material (considered to reflect the first use of the region) comes from PT 12-A(2) and is bracketed by two identical ages of 36±3ka; significant numbers of artefacts were found in the spits immediately beneath this peak suggesting a date of initial occupation closer to 40ka may be more likely. Williams et al. (2012) initially postulated that the lower peak of artefacts at PT 12 may have been in the order of 35ka, but rejected such a proposition due to the caveats associated with the ages. The findings at PT 12-A(2), demonstrate that the lower peak at PT 12 was indeed 35ka in age.

Following initial occupation at PT 12 and PT 12–A(2), there is a suite of ages through the artefact-bearing deposits, ranging from 36ka through to 4.8ka (Figure 6). Two distinct assemblages were evident in all of the excavations: A lower assemblage dominated by tuff and characterized as Capertian (see below for terms) focused between ~26 and 8ka; and an upper assemblage dominated by silcrete and characterized as Bondaian focused between 15 and 0ka, and primarily at <5ka. Using age-depth models (polynomial second order) for each area, peaks in artefact numbers associated with the lower assemblage are evident at 11ka at PT 12, 16.2ka and 11.6ka at PT 12-A(1), 21ka and 12ka at PT 12-A(2), 26ka (test pit 89) and 19.5ka (test pit 56) at PT 12-B. Peaks in the upper assemblage were found at 7ka and 5.5ka at PT 12; 15ka, 4.8ka and 0.45ka at PT 12-A(1); 8.5ka and 2.5ka at PT 12-A(2); 8.3ka(test pit 56) and 5.8ka (test pit 89) in PT 12-B. Backed artefacts, one of the main diagnostic tool types of the Bondaian technology, were recovered from deposits dating to as early as 12ka in PT 12-A(2) and 8.3ka at PT 12-B (test pit 56). Proliferation of this tool type at PT 12 was initially considered to date to ~5.5ka (Williams et al. 2012), although the larger and less disturbed assemblage recovered from PT 12-A(2) suggests an age closer to 2.5ka, which is more consistent with wider archaeological literature (e.g. Attenbrow, 2004; Hiscock, 2008; Hiscock and Attenbrow, 2005). A shift from Capertian style scrapers to backed artefacts is also evident at ~8.5ka in PT 12-A(2).

In general, radiocarbon dating proved unfeasible, since agricultural activities across the site included regular burning of vegetation in the late 20th Century, and examination of the soil profile showed that charcoal from this process had moved downwards. However, one date was obtained from a discrete hearth dug into the sand body at PT 12-A(1), and provides the most reliable age of 2.3-2.6ka for the upper assemblage. This correlates well with the date of the backed artefact proliferation at PT 12-A(2) (Table 2).

3.3 Lithics

Across PT 12, PT12-A and PT 12–B, the artefacts could be divided into two broad horizons based on assemblage composition and vertical location (Figure 6): 1) an upper horizon composed primarily of silcrete and quartz artefacts, including backed artefacts; and 2) a lower horizon of amorphous pebble-tools and manuports composed of tuff, with lesser occurrences of volcanic and quartzite materials. This lower horizon had multiple peaks and troughs and probably represents a number of different periods of occupation between 36 and 8ka. While the two horizons are considered to reflect quite different temporal phases, there is rarely a physical gap between the two assemblages, and frequently the two cross over. This is likely the result of some vertical displacement within the upper parts of the sand body through bioturbation (tree roots and insect burrows were frequent) and the mixing of the upper 40-50cm of the profile by ploughing. The shift between the two horizons, most evident in the reduction in use of tuff, appears to have occurred by ~8-7ka. Williams et al. (2012) believed that this age probably reflected the end of the Terminal Pleistocene occupation of the region, followed by a hiatus in occupation until the late Holocene; further evidence presented here supports this view.

The assemblage from the lower horizon had features typically found in the Australian core tool and scraper tradition (Hiscock and Attenbrow, 2005), also termed Capertian. This broad, pan-continental category encompasses all Pleistocene and early Holocene assemblages and is defined by the dominance of tuff (grey chert) and the presence of large, concave and nosed "scrapers, knives, dentated saws and burins, with a few choppers, unspecialized cores, uniface pebble implements and hammerstones" (McCarthy 1964:141). With specific reference to PT 12-A(2), where the majority of the artefacts were recovered, the tools were dominated by large stepped, notched and concave scrapers and composed primarily of tuff (Tables 4 and 5; Figure 6). For the most part, however, artefact production was relatively simple, with a succession of flakes being struck from river pebbles before one was selected for further reduction. The cores were mainly uni-directional, showing no evidence of systematic core preparation, and a preference to produce and transport larger flakes (Table 4). Flakes were typically larger and heavier in this horizon, although much more variable, compared to the silcrete-dominated horizon above. The large numbers of small tuff flakes indicated that retouching and re-sharpening of tools and the continued reduction of small cores occurred along the ridgeline. Few artefacts retained cortex, suggesting that primary reduction was occurring elsewhere. However, the main raw material source is thought to be cobbles from the nearby river. This is supported by the discovery of numbers of large river cobbles (n=223 at PT 12-A) generally in the lower depths. The unworked cobbles frequently had evidence of burning and heat-fracturing, indicative of use as heat retainers or hearth-stones.

Artefact breakage rates were high throughout PT 12-A(2) (n=6,045; 71%), especially between spits 14-19 (~36-21ka) at the onset and peak of the LGM. This has been used to indicate site-use intensity (greater trampling equating to more damage to the assemblage). However, when applying methods outlined in Smith (2006) in which artefact attributes are assigned a mobility ranking (e.g. greater tool diversity equating to lower mobility or heavier average weight suggestive of higher mobility), the assemblage suggests hunter-gatherer use of the area reflected repeated short term occupation, rather than long term base camps, through this period (Table 5; Figure 7).

McCarthy (1964:143) defines the Bondaian culture of the Sydney region as "having trimmed blocks, a few elouera, burins, flake fabricators, scrapers of many kinds, a wide range of geometrical microliths, and the Bondi point in large numbers; it marks the beginning of gum hafting of knapped implements and the appearance of the ground edge in eastern New South Wales." Attenbrow (2010:153-158) expands on this definition by noting that implements and associated debitage are much smaller in average size and weight than those from earlier assemblages, and that there is an increase in the use of silcrete and quartz coupled with use of the bipolar percussive technique over time (especially from 3-0ka). At PT 12-A(2), there is a significant shift to the use of silcrete and quartz combined with a greater diversity in the raw material types used in the upper spits (1-11). The complete flakes and flake scars on cores are more elongated in form than in the lower assemblage. These characteristics are indicative of a more systematic core reduction, associated with the manufacture of backed implements (Bondi points or geometric microlithics) that are generally made on small, light elongated flakes (Tables 4 and 5). The absence of large complete flakes of silcrete (>25mm) indicates that silcrete was obtained from further away than the tuff, most likely from outcrops in the Riverstone/Plumpton Ridge area, some 12 km to the southwest of PT 12 (Corkhill, 1999). Cortex is often absent, which similarly suggests transport from some distance and where present it is often dominated by water-rolled characteristics. Increasing evidence of primary silcrete outcrop exploitation is present in the upper deposits. Again there are a large number of broken flakes in the assemblage, but fewer than in the lower assemblage; a larger number of these breaks are probably a result of the more complex and delicate manufacturing techniques required for backed artefacts, rather than trampling. Decreasing relative mobility through this time (Table 5; Figure 7), along with increased discard rates (Table 4), indicates increasing and more prolonged use of this region, perhaps akin to a base camp, in the late Holocene, despite overall artefact numbers being lower than in the earlier horizon.

There were significant issues with the findings and interpretation of the upper assemblage at PT 12 based on the level of disturbance of the deposit and caveats associated with the OSL ages. Williams et al. (2012) believed that there was a hiatus between the two assemblages, but this could not be proven and tentative conclusions were made that the upper assemblage was an unusually early Bondaian industry. The upper assemblage at PT 12-A is larger and appears less disturbed. Here, we find that a proliferation of backed artefacts and the increasing use of quartz both occur at ~2.5ka (spits 3 and 4), and in combination with a hearth feature in PT 12-A(1) dating to ~2.3ka, conclude that the upper assemblage is likely of middle or late Bondaian age (3-0ka). We believe that a hiatus between the two assemblages is likely, with an abandonment of the site between ~8 and 3ka.

The results of the excavations at PT 12-A and -B correlate closely with the findings from PT 12. In total, the three excavations at PT 12, PT12-A and PT12–B have recovered 11,402 stone artefacts, of which 8,544 (75%) come from PT 12-A(2) (Table 3). Artefact densities varied from as low as $5/m^2$ in the back-dunes and swales of PT 12-B up to $203/m^2$ at PT 12-B (test pit 56). On the edge of the ridge within the main fore-dune, average densities were generally $>35/m^2$. Based on roadside sections and aerial photography, the sand body appears to run continuously from PT 12-A to PT 12-B (a distance of 3km), and is consistently at least 100-150 m wide (Figure 1). Using this area and the range of artefact densities outlined above, potentially between 2.3 and 94 million artefacts may be present within the sand body. While speculative, using Hayden's (1977) artefact production rates of 150 artefacts per year for a nuclear family in the western deserts, this could equate to between 1 and 22 such families annually using the region between 36-8ka.

3.4 Summary of the Excavation Findings

The excavations at a number of different locations within the wider PT 12 sand body have all produced similar results. Specifically, they have found that a small dune-field on the edge of the Hawkesbury River initially formed through fluvial deposition in MIS 6, with extensive aeolian reworking in the last 30ka. The fore-dune was a focus for Aboriginal activity occurring over two phases at 36-8ka and <5-0ka.

The earliest phase of activity began by 36ka (and potentially earlier), with increased use during the LGM and into the Terminal Pleistocene. During this period Aboriginal people were exploiting the gravel beds and raw materials of the nearby Hawkesbury River that would have been exposed by the entrenchment of the river due to lower sea-levels. Worked tuff cobbles were brought onto the sand body, and then further worked into tools, mainly a variety of scrapers. Excavations at both PT 12-A and PT 12-B suggest that cobbles of quartzite and volcanic raw materials were also collected as hearthstones. Extensive breakage suggests that repeated trampling and/or intense occupation of the region occurred throughout this period, and especially through the peak of the LGM. However, occupation consisted of regular repeated use of the site, with PT 12 sand body probably forming one of several locales in a point-to-point subsistence strategy or cryptic refugium, rather than a classic ethnographic home-base strategy (Smith, 2013).

The upper soil profile at PT 12 was generally impacted by agricultural practices, and this has hindered our understanding of the upper assemblage. Williams et al. (2012) believed that the upper assemblage was probably of late Holocene age, following a hiatus in occupation between ~8-5ka, but OSL ages indicated that it may have been earlier. Excavations at PT 12-A and PT 12–B had similar mixing issues, but a larger assemblage and the recovery of a hearth in the upper layers provides greater support for a late Holocene age. Specifically, both the hearth, and the proliferation of backed artefacts at PT 12-A indicate that the later peak in Aboriginal activity occurred at ~2.5ka; and therefore a hiatus between 8ka and at least 5ka is more likely. The upper assemblage was dominated by silcrete and quartz, neither local to the area, and indicates a focus on backed artefact and tool production. While artefact numbers were lower in these upper deposits, discard rates and evidence of declining relative mobility indicate a more intense use of the region in the late Holocene.

4. Discussion

There still remains controversy surrounding how rapidly hunter-gatherer populations increased following initial colonisation of the continent. Birdsell (1957) was the first to propose a model for saturation of the prehistoric continent by a hunter-gatherer population that rapidly achieved ethnographic population densities. Using modern analogues, he argued that a small founding population could have colonised the continent in only 2,000 years - populations 'budding off' into new areas as carrying capacity was reached. Conversely, Beaton (1983), Lourandos (1983, 1997) and others proposed an alternative model, suggesting populations were consistently low in the Pleistocene, before exponentially expanding in the mid- to late Holocene. More recently, Williams (2013) explored these ideas using radiocarbon data from archaeological sites across Australia. He found that populations remained low in the Pleistocene (but at levels significantly higher than previously thought and comparable with the early Holocene), before increasing in a step-wise manner from 12 to 0.5ka. Spatially, archaeological evidence from the southern parts of Australia supports this model, with only two sites reliably exhibiting visitation prior to 40ka, namely Devil's Lair in southwest WA, and the burials at Lake Mungo (LMIII being dated to 42±3ka) (Bowler et al., 2003). Other less reliable findings also include a single flake in pre-40ka deposits at Box Gully (Richards et al., 2007), a possible midden at Point Ritchie dated to 49-43ka (Sherwood et al., 1994), and five artefacts recovered from parts of the Cranebrook Terrace dated to >42ka (Nanson et al., 1987).

In contrast to Williams' model, however, there is little evidence of increasing populations prior to the LGM with a pattern of ephemeral activity and visitation persisting until the Terminal Pleistocene. For example, excavations at Bend Road, an open site near Keysborough, recovered only 17 artefacts from deposits dating to before 30ka (Hewitt and Allen, 2010); Koettig (1987) recovered 49 artefacts associated with a hearth dated to 40-37ka adjacent to Fal Brook, a tributary of the Hunter River; a short episode of hearth features, faunal remains and 14 artefacts were recovered from a lunette adjacent to Box Gully deposited between 32 and 26ka; and remains of hearths and midden materials at Keilor deposited before 31ka (Gallus, 1976). Only the Willandra Lakes system and parts of southwest and central Tasmania (from ~ 35ka) show more extensive occupation and run counter to this view (e.g. Balme and Hope, 1990; Webb et al., 2006; Smith et al., 2008; Cosgrove, 1995; Stern and Allen, 1996; Allen, 1996). Through the findings at PT 12, we can now demonstrate that the Hawkesbury River corridor in western Sydney was also a likely area of prolonged occupation prior to the onset of the LGM. The ongoing and intense use of PT 12-A(2), along with low relative mobility, prior to the LGM suggests a permanent regional population in the Sydney Basin (rather than occasional visitation), and lends significant support to a more substantial occupation in the southeast corner of Australia by this time. These levels of occupation and activity were maintained, if not enlarged, through the Terminal Pleistocene.

The focus of occupation on the PT 12 sand body by this time is not unexpected, as the site is surrounded by a range of biomes (e.g. mountains, rolling hills, incised creek systems, etc) and located on a fluvial system that probably had permanent flow from increased summer snow melt of glacial ice in the upper reaches of the catchment (Williams et al. 2012, 2013). More locally at Pitt Town, the entrenched river had a number of useful resources, including a wide range of stone raw materials, as well as food and wood materials likely associated with a large river system. In addition, colonization models have previously indicated that movement and expansion probably followed the coastal fringe (Bowdler, 1977) and large water-courses into the interior of the continent (White and O'Connell, 1982). The Hawkesbury River fulfils these conditions providing easy access from the coast to >60km inland, even further when considering Pleistocene low sea-stand; the site was also largely unapproachable from the west due to the Blue Mountains. The presence of SGCD 16 near the Hunter River suggests other nearby river systems may have been used in a similar fashion prior to the LGM.

The LGM in Australia was a two-step period of significant cooling and increased aridity beginning ~30ka and peaking between ~23-18ka (e.g. Petherick et al., 2011; Reeves et al. 2013; Williams et al., 2009). Human response to the LGM has formed a persistent theme in Australian archaeological research and interpretations for over 30 years (e.g. Veth, 1989a, 1993; O'Connor et al., 1993; Smith, 2013). Research has primarily focused on the arid zone and suggested the importance of refugia – well-watered ranges and major riverine systems – and the abandonment of large tracts of desert and marginal country (Lampert and Hughes, 1987; Smith, 1988; Hiscock, 1988; Veth, 1989b). Using geo-spatial techniques, Williams et al. (2013) re-explored these ideas at a continental scale, and similarly identified a number of broad-scale refugia during the LGM, including the temperate Sydney Basin. The findings at PT 12-A(2) showing increased artefact numbers at and immediately following the LGM supporting the identification of the Hawkesbury River as a refuge.

While previous research has focused on the broad-scale nature of hunter-gatherer behavior at the LGM, Smith (2013) undertook detailed review of a number of individual refuges, and considered that abandonment of entire regions was unlikely. Rather, he considered archaeological evidence more accurately reflected cryptic refugia – a thinning out of populations across the country into pockets of micro-habitat. Specifically, he found that the classic ethnographic refuges (the home-base model) were not supported, but rather a point-to-point system of subsistence in which increasing residential mobility across key resource localities with limited season dispersal into back country, was more realistic. While Smith's work was focused in the arid zone, the results of PT 12-A(2) very much support the point-to-point model being applicable for temperate biomes. Our results show that at the onset of the LGM, both artefact numbers and relative mobility increase (Table 5, Figure 7), which strongly suggests the locality was used more intensely but not as a base-camp, rather for more frequent shorter visits. During the actual peak of the LGM (spit 14), relative mobility decreases slightly (and artefact diversity increases slightly) indicating that PT 12 may have formed a *key* locality in a network of sites or points used by hunter-gatherers through this period - perhaps used for slightly longer than at other times in the late Pleistocene. This pattern is, however, brief, with high relative mobility evident in the spits immediately above the LGM. Currently, no other points in this system have been discovered, although archaeological deposits found at the Windsor Museum (Williams et al., 2012), 5km away, and the banks of the Parramatta River (McDonald, 2008), 27km away, are old enough to form other possible nodes; other currently un-investigated ridge-lines along the Hawkesbury River are also strong possibilities.

Immediately after the LGM at PT 12-A(2) (and probably PT 12), artefact numbers diminish as mobility reaches its highest levels, suggesting either an issue with the refugium or more likely decline in local populations. Williams (2013) believed that the period after the LGM saw significant continent-wide population collapse (up to 60%) due to increasing temperatures initially outpacing precipitation and leading to even drier conditions than the LGM (Markgraf et al., 1992; Kershaw and Nanson, 1993); and results at PT 12 likely reflect this. However, other parts of PT 12 show ongoing, and in some cases increasing artefact numbers through this period. Despite these disparate results across the site, based on the assemblage contents and level of relative mobility, it appears likely that the point-to-point system initiated in the LGM remained active in some form until the Holocene transition, and that PT 12 formed a part of this network, although the structure or condition of the local population cannot be readily discerned.

From ~12-8ka, a further pulse of occupation is evident at each of the excavation sites, and again signals an increasing utilization of the area by hunter-gatherers. The results here suggest a return to behaviour similar to that seen through the LGM, although climatically there is little reason for this. We can only speculate as to the reason for the repeated, and likely short, visits to the region over this time: It may reflect a response to the Antarctic Cold Reversal (14-12ka) (Williams, 2013), or it may form a response to increasing populations in tandem with loss of the coastal fringe through sea-level rise (Lambeck and Chappell, 2001; Lambeck et al., 2002; Lewis et al., 2008). The latter scenario possibly leading to localised resource stress, and re-initiating behaviour common to glacial conditions. Both Williams (2013) and Ulm (2013) consider that the early Holocene saw significant demographic, economic and social changes, and these may also have influenced the archaeological record at PT 12 at this point.

The upper part of the site is heavily disturbed, and interpretation of the archaeological record remains tentative. We are now more confident that the upper assemblage is of late Holocene age, and conforms with hunter-gatherer occupation and behaviour widely documented in the Sydney Basin from this period (Attenbrow, 2010; McDonald, 2008; White and McDonald, 2010). There is some suggestion of an abandonment of the site by ~8ka, which runs counter to evidence of increasing numbers of archaeological sites (*a priori* populations) at this time, but may reflect the importance of stone raw materials in the region, access to which was lost through the river rising, with sea-level change, and submerging the gravel deposits (Williams et al. 2012). Occupation of a number of sites located further upstream from PT 12 appears to have been initiated immediately after 8ka (e.g.

Jamisons Creek and Regentville 1 (Kohen et al., 1984; McDonald, 1995)), and reflects re-organisation of settlement patterns to use the stone raw material resources further up the catchment. Further investigation of the upper deposits of PT 12 is required, preferably within an area where agriculture has been minimal in the past.

5. Conclusion

The findings at PT 12 provide the first reliable evidence of a regional population and ongoing occupation in this part of Australia during the Terminal Pleistocene. Prior to this, archaeological sites were generally small and ephemeral, indicating only brief visitation across the southern parts of the continent. Ongoing and fairly intense occupation at PT 12 lends further support to the conclusions of Williams (2013), which suggested populations in the Pleistocene, while small, were greater than previously thought, and therefore able to maintain 'permanent' regional populations. Here, we believe that 36ka is the threshold at which populations began to expand and form viable regional groups. The location of PT 12 on a large river system with significant mountains acting as barriers to the west also provides support for colonization models that suggest early explorers utilized the coastal fringe and riparian corridors for moving across the continent.

Recent studies by Williams et al. (2013) postulated that the Sydney Basin may have been a refugium during the onset and peak of the LGM, primarily due to the availability of permanent water from increased snow melt of glacial ice in the Blue Mountains and Australian Alps. Results at PT 12 indicate this is at least partially correct, demonstrating a focus of activity and use through this period. In addition, we undertook further exploration on the nature of the refuge, based on work by Smith (2013). Specifically, we believe that the greater number of artefacts in combination with inferred high relative mobility through this period suggest that PT 12 formed a cryptic refuge - one of a series of nodes within a point-to-point subsistence system, in which key localities were used as part of a network by highly residentially mobile hunter-gatherers. No other LGM archaeological sites that may form part of this point-to-point strategy have yet been identified in the Sydney Basin, although other parts of the Hawkesbury River riparian corridor are a possibility. This subsistence strategy appears to have been maintained throughout the Terminal Pleistocene, although the period immediately after the LGM shows significant reduction in Aboriginal populations. A pulse of occupation is evident between ~12 and 8ka, and also appears to be based on the same point-to-point system, the reasons for which are unclear. We speculate that this may have been the result of increasing population pressure in the region following sea-level rise and inundation of the coastal fringe, and a return to resource stress behaviours.

The final phase of the site is heavily disturbed, but we have greater confidence in an abandonment of the region in the mid Holocene, before re-occupation in the last few thousand years. The reason for the abandonment remains unclear, but may reflect the loss of access to stone raw materials on this section of the Hawkesbury at around this time due to river aggradation, leading to a re-organisation of settlement patterns. Occupation of several sites further upstream, near currently exposed river gravels, appears to begin from ~8ka.

Finally, we wish to highlight the importance of the Hawkesbury River corridor as a new area within which to focus exploration of early Aboriginal occupation of Australia. This should be a high priority area for researchers because the banks of the Hawkesbury River are being rapidly developed, and sites such as PT 12 are becoming increasingly rare. Local and State government should also consider long-term planning that ensures representative samples of the Pleistocene dune landforms on the fringe of the Hawkesbury River are retained due to their rarity, cultural importance to the Aboriginal community, and significant archaeological value. Key future research should focus on further verification of the results from the PT 12 sand body at other areas along the riparian corridor; a greater exploration of the last phase of Terminal Pleistocene occupation; and identification of areas where surface disturbance may be low to allow greater understanding of the latest phase of occupation.

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Tables

Table 1. Summary of OSL ages recovered from PT 12, -A and –B.

Table 2. Summary of a radiocarbon data obtained from an intrusive hearth within PT 12-A(1).

Table 3. Summary of the lithic data collected from PT 12, -A and –B. Both raw counts and percentages (expressed in brackets) are presented for a range of diagnostic features and raw material types.

Table 4. Summary of main raw material types from PT 12-A(2) by both raw counts (n) and weight (g). Data are presented by spit, each of which are given an interpolated age range and length in years based on the OSL chronology and a second order polynomial age depth model of GL11072 – 11081, and assuming no disconformities.

Table 5. Index of relative mobility based on the PT 12-A(2) assemblage using methods after Smith (2006). Each artefact indices has been assigned a rank of between 1 and 23 (presented in brackets), with the greater the number reflecting higher mobility. Each of the individual rankings are then summed together to form a rank sum, which is used to provide an overall indication of relatively mobility by spit.

Figures

Figure 1: Maps of: A) sites referred to in the text (1-Carpenter's Gap 1; 2- Narwala Gabarnmang; 3-Malakunanja II; 4- Nauwalabila 1; 5-Riwi; 6-Devil's Lair; 7-Cranebrook Terrace; 8-Bass Point; 9-SGCD 16; 10-KII Shaws Creek; 11-RTA-G1; 12-PT 12; 13-Lake Mungo; 14-Box Gully; 15-Point Ritchie; 16-Bend Road; 17-Keilor; 18-Jamisons Creek; 19-Regentville 1; 20-Windsor Museum); B) detail of sites in western Sydney (using same numerical codes); and C) detailed location of PT 12, -A and –B, and the potential extent of the sand dune system.

Figure 2: Photograph of PT 12-A(1), a 25 m^2 open area excavation located some 300 m from the edge of the ridge. Note the hearth feature near the scales, a date from which provided the only secure date for the upper archaeological assemblage. Also note the pebbly texture in the lower profile, a result of ironstone and manganese precipitation from an elevated water table. Scale=20cm increment.

Figure 3: Photograph of PT 12-A(2), a 75m^2 open area excavation on the deepest part of the deposit on the edge of the ridge. A main tributary of the Hawkesbury River is immediately downslope behind the trees in the background. In general, excavations reached 120 cm below surface, with one exploratory test pit being dug to 250 cm below surface. Scale=20cm increment.

Figure 4: Photograph and simplified scaled drawing of PT 12-A(2), showing the location of OSL samples and main sedimentological units (descriptions after Williams et al., 2012). The main artefact concentrations are also presented adjacent the section showing both high (grey band) and peak (black square) numbers. Scale = 20 cm increment.

Figure 5: Particle size analysis of: A) PT12-A(2); B) PT 12-B, test pit 56; and C) PT 12-B, test pit 89. In relation to (A), soil samples were collected as discrete 1 cm samples at 5 cm intervals down the profile; for (B) and (C), contiguous bulk samples 5cm in size were collected down the profile. All samples were measured using a Malvern Mastersizer 2000®. Grain size definitions are presented after

Gale and Hoare (1991). Note at PT-12A(2), the lowest samples are dominated by coarse grain size, suggestive of fluvial origins, with a trend towards finer material after 60ka, and especially through MIS 2 and 3. This latter period is considered to represent aeolian processes at work, and is further evident by the deposition of parts of the sand body at PT 12-B only in the last 30-40ka.

Figure 6: Summary diagram of selected artefact materials and OSL ages recovered from excavations at: A) PT 12-B (includes all artefactual material from across the 65 test pits excavated at this location); B) PT 12 (Williams et al., 2012); C) PT 12-A(1); and D) PT 12-A(2). OSL ages are presented as black circles. One radiocarbon date from an intrusive hearth is shown as a black square. Individual tools are presented as symbols to the right of the graphs: squares = scrapers, circles = backed artefacts. The generally disturbed plough zone is also shown as grey banding.

Figure 7: Relative mobility of the artefact assemblage of PT 12-A(2) after rank sum data in Table 5, and methods outlined in Smith (2006). Here, the higher the number, the greater the relative hunter-gatherer mobility.

Table 1

Location	Test-pit	Spit[†]	Depth (cm below surface)	Depth (m AHD)	Lab Code	Equivalent Dose (Gy)	K (%)*	U (ppm)*	Th (ppm)*	Cosmic Dose Rate (Gy/ka)	Water Content (%)	Total Dose Rate (Gy/ka)	Age (ka)[∏]
PT 12	C10	6	30	24.025	GL10004	4.7±0.6	0.46±0.03	2.77±0.34	0.88±0.07	0.16±0.02	5±1	1.00±0.05	4.7±0.6
PT 12	C10	12	56	23.74	GL10005	7.7±0.7	0.47±0.03	3.38±0.34	0.72±0.02	0.16±0.02	5±1	0.98±0.04	7.9±0.8
PT 12	C10	15	77	23.535	GL10006	12.4±0.6	0.46±0.03	3.31±0.33	0.75±0.06	0.15±0.02	5±1	0.94±0.04	13±1
PT 12	J10	22	110	23.155	GL10008	47.7±2.4	0.44±0.03	2.88±0.33	0.83±0.06	0.14±0.01	5±1	0.93±0.04	51±3
PT 12	C10	26	130	23.025	GL10007	70.3±3.7	0.54±0.03	3.93±0.37	1.05±0.07	0.14±0.01	6±2	1.12±0.05	63±4
PT 12	H10	36	180	22.52	GL10009	143.3±11.8	0.64±0.04	4.15±0.34	0.79±0.06	0.13±0.01	12±3	1.13±0.05	127±12
PT 12-A(1)	J3	12	60	23.11	GL11082	12.1 ± 1.5	0.39 ± 0.03	0.73 ± 0.06	2.30 ± 0.26	0.16 ± 0.02	6 ± 2	0.82 ± 0.05	15 ± 2 (2)
PT 12-A(1)	J3	16	80	22.91	GL11083	23.0 ± 1.4	0.40 ± 0.03	0.81 ± 0.07	3.19 ± 0.33	0.15 ± 0.02	8 ± 2	0.87 ± 0.05	26 ± 2 (2)
PT 12-A(2)	D1	9	43	25.03	GL11072	13.2 ± 1.1	0.51 ± 0.03	0.96 ± 0.07	4.89 ± 0.38	0.16 ± 0.02	7 ± 2	1.14 ± 0.06	12 ± 1 (1)
PT 12-A(2)	D1	11	52	24.94	GL11073	19.9 ± 1.2	0.53 ± 0.03	1.03 ± 0.07	5.11 ± 0.39	0.16 ± 0.02	6 ± 2	1.19 ± 0.06	17 ± 1 (1)
PT 12-A(2)	D1	14	68	24.78	GL11074	24.3 ± 1.6	0.52 ± 0.03	1.04 ± 0.07	4.97 ± 0.38	0.16 ± 0.02	6 ± 2	1.17 ± 0.06	21 ± 2 (1)
PT 12-A(2)	D1	17	82	24.64	GL11075	45.7 ± 2.2	0.59 ± 0.03	1.04 ± 0.07	5.04 ± 0.39	0.15 ± 0.02	5 ± 1	1.26 ± 0.06	36 ± 3 (2)
PT 12-A(2)	D1	21	98	24.48	GL11076	57.1 ± 3.0	0.56 ± 0.03	0.97 ± 0.07	5.22 ± 0.39	0.15 ± 0.01	5 ± 1	1.21 ± 0.06	47 ± 3 (3)
PT 12-A(2)	I1	15	68	24.78	GL11077	26.1 ± 2.0	0.58 ± 0.03	1.14 ± 0.08	4.87 ± 0.39	0.16 ± 0.02	5 ± 1	1.26 ± 0.06	21 ± 2 (2)
PT 12-A(2)	I1	19	90	24.56	GL11078	45.2 ± 2.8	0.58 ± 0.03	1.13 ± 0.08	4.70 ± 0.39	0.15 ± 0.01	4 ± 1	1.24 ± 0.06	36 ± 3 (2)
PT 12-A(2)	I1	24	115	24.31	GL11079	67.2 ± 3.9	0.55 ± 0.03	1.09 ± 0.07	4.75 ± 0.38	0.14 ± 0.01	5 ± 1	1.20 ± 0.06	56 ± 4 (3)
PT 12-A(2)	E5	33	160	23.86	GL11080	112.5 ± 5.3	0.56 ± 0.03	1.06 ± 0.07	4.62 ± 0.38	0.13 ± 0.01	6 ± 2	1.16 ± 0.06	97 ± 7 (5)
PT 12-A(2)	E5	48	237	23.09	GL11081	172.5 ± 8.0	0.67 ± 0.04	0.92 ± 0.07	4.47 ± 0.38	0.12 ± 0.01	6 ± 2	1.21 ± 0.07	143 ± 10 (8)

PT 12-B	89	9	42	17.67	GL11009	4.9±0.5	0.40±0.03	0.66±0.06	2.34±0.31	0.16±0.02	3±1	0.84±0.05	5.8 ± 0.7
PT 12-B	89	14	66	17.43	GL11010	12.8±0.9	0.48±0.03	0.70±0.06	2.34±0.28	0.15±0.02	4±1	0.90±0.05	14 ± 1
PT 12-B	89	19	91	17.18	GL11011	31.0±2.4	0.43±0.03	0.66±0.06	2.67±0.28	0.15±0.01	5±1	0.86±0.05	36 ± 3
PT 12-B	56	7	35	20.52	GL11012	4.1±0.4	0.43±0.03	0.75±0.06	2.22±0.26	0.16±0.02	3±1	0.88±0.05	4.6 ± 0.5
PT 12-B	56	11	54	20.33	GL11013	7.2±0.08	0.40±0.03	0.71±0.06	2.69±0.32	0.16±0.02	3±1	0.87±0.05	8.3 ± 1.0
PT 12-B	56	13	64	20.23	GL11014	8.0±0.6	0.39±0.03	0.73±0.06	2.44±0.27	0.16±0.02	3±1	0.85±0.04	9.5 ± 0.8
PT 12-B	56	19	93	19.94	GL11015	26.0±1.9	0.42±0.03	0.68±0.06	2.86±0.32	0.15±0.01	4±1	0.88±0.00	30 ± 3

† All spits are presented in 5 cm intervals. To allow direct comparison, all samples from PT 12-A are also presented in 5cm intervals, although they were excavated in 10cm spits.

* K, U and T were measured using Ge gamma spectrometry in the laboratory following collection of the samples.

∏ The ages are shown using present day as their reference point, i.e. GL10004 is 4700 years ago from AD 2010. Ages shown in red have analytical caveats, although only GL10009 was recommended for rejection. Uncertainties in age are quoted at 1σ confidence, are based on analytical errors and reflect combined systematic and experimental variability and (in parenthesis) experimental variability alone.

Table 2.

Location	Test-pit	Spit	Depth (cm below surface)	Depth (m AHD)	Lab Code	Radiocarbon Date	∂13C	F14C%	Calibrated Age*
PT 12-A(1)	A8	9-10	47	23.15	Wk-33094	2504 ± 25	-27.5 ±0.2	73.2± 0.2	2355 – 2690

*Calibrated using Oxcal (verion 4.1) (Bronk Ramsey, 2009) and INTCAL09 (Reimer et al 2009) at 95.4% confidence levels.

Table 3

Location	PT 12	PT 12-A(1)	PT 12-A(2)	PT 12-B
Number of artefacts	1,353	867	8,544	638
Square metres Excavated	25	25	75	65
Artefact Density (per m²)	46	36.7	113.2	5.45
Number of Tuff artefacts	946 (69.9)	596 (69)	5,831 (68)	322 (51.7)
Number of Silcrete artefacts	220 (16.3)	83 (10)	1,014 (12)	217 (34.8)
Number of other raw materials	187 (13.8)	188 (21)	2,566 (27.2)	99 (15.9)
Number of complete flakes	121 (8.9)	48 (5.5)	1,068 (12.5)	115 (18)
Number of tools	0 (0)	3 (0.3)	121 (1.4)	13 (2.0)
Number of cores	0 (0)	3 (0.3)	70 (0.8)	0 (0)

Table 4

Spit	Depth (cm)	Interpolated Age of spit (ka)	Spit Duration (years)	Main Raw Material Types										Assemblage Total		Total number of artefacts/100years
				Quartz		Silcrete		Quartzite		Tuff		Volcanic				
				n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	
1	0-5	0.22-0.96	735	9	3.00	8	12.30	3	2.30	1	0.10	0		**21**	**17.70**	2.86
2	5-10	0.96-1.84	884	55	76.90	64	56.30	27	415.70	48	225.72	23	476.40	**227**	**1,261.72**	25.68
3	10-15	1.84-2.88	1032	122	86.00	111	137.30	46	651.10	93	191.00	32	50.10	**411**	**1,118.70**	39.83
4	15-20	2.88-4.06	1181	118	103.70	114	117.20	39	148.90	90	71.00	26	181.60	**391**	**625.60**	33.11
5	20-25	4.06-5.39	1330	86	37.40	89	93.10	26	436.00	77	62.60	47	620.50	**332**	**1,256.80**	24.96
6	25-30	5.39-6.86	1478	41	20.20	54	124.90	11	57.00	60	59.40	10	77.90	**177**	**339.50**	11.98
7	30-35	6.86-8.49	1627	37	11.70	56	67.30	20	393.50	108	138.70	20	976.30	**244**	**1,588.80**	15.00
8	35-40	8.49-10.27	1776	26	24.80	104	341.20	34	627.26	228	682.20	51	1,344.60	**446**	**3,022.66**	25.11
9	40-45	10.27-12.19	1924	16	4.60	60	81.60	23	514.80	250	464.30	32	691.20	**383**	**1,757.60**	19.91
10	45-50	12.19-14.27	2074	10	1.80	51	107.30	12	112.70	221	274.30	13	72.30	**308**	**568.50**	14.85
11	50-55	14.27-16.49	2222	11	1.40	29	14.90	9	144.90	179	162.22	11	61.10	**239**	**384.52**	10.76
12	55-60	16.49-18.86	2370	14	18.10	26	14.40	7	12.90	185	272.80	14	196.00	**248**	**514.50**	10.46
13	60-65	18.86-21.38	2520	9	1.90	26	21.10	15	394.80	315	431.50	26	753.20	**394**	**1,602.70**	15.63
14	65-70	21.38-24.05	2668	16	32.60	36	20.40	20	83.40	488	462.20	28	475.40	**590**	**1,075.90**	22.11

Spit	Depth (cm)	Interpolated Age of spit (ka)	Spit Duration (years)	Main Raw Material Types										Assemblage Total		Total number of artefacts/100years
				Quartz		Silcrete		Quartzite		Tuff		Volcanic				
				n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	
15	70-75	24.05-26.86	2816	5	10.10	20	8.50	12	125.30	369	424.50	16	351.00	**424**	**920.10**	15.06
16	75-80	26.86-29.83	2966	7	8.10	10	10.20	16	476.20	433	347.61	30	357.20	**496**	**1,199.31**	16.72
17	80-85	29.83-32.94	3114	8	6.20	18	6.40	16	137.50	496	509.50	34	1,002.60	**574**	**1,662.60**	18.43
18	85-90	32.94-36.20	3263	11	5.10	19	12.50	18	386.10	542	383.60	57	602.50	**650**	**1,390.40**	19.92
19	90-95	36.20-39.62	3412	13	10.10	15	4.00	13	153.90	461	339.40	34	534.20	**538**	**1,042.80**	15.77
20	95-100	39.62-43.18	3560	14	2.40	15	204.00	10	34.20	389	239.30	22	107.20	**451**	**587.20**	12.67
21	100-105	43.18-46.89	3709	9	4.70	19	290.90	12	18.30	277	391.10	17	122.30	**334**	**827.30**	9.01
22	105-110	46.89-50.74	3858	10	14.60	41	80.70	8	4.00	244	357.90	10	39.80	**314**	**497.80**	8.14
23	110-115	50.74-54.75	4006	2	1.00	14	18.40	2	0.60	147	148.70	5	202.30	**170**	**371.00**	4.24
24	115-120*	54.75-58.90	4155	10	1.20	14	6.50	2	0.40	115	144.50	5	15.20	**146**	**167.80**	3.51
25				0	-	0	-	0		5	0.50	1	13.60	**6**	**14.10**	
26				2	0.40	1	0.40	0		5	0.50	1	23.00	**9**	**24.30**	
27				0	-	0	-	0		2	0.20	0		**2**	**0.20**	
35				0	-	0	-	0		1	0.10	0		**1**	**0.10**	
37				0	-	0	-	0		1	0.10	0		**1**	**0.10**	
41				1	0.60	0	-	0		1	0.30	0		**2**	**0.90**	

Spit	Depth (cm)	Interpolated Age of spit (ka)	Spit Duration (years)	Main Raw Material Types										Assemblage Total		Total number of artefacts/100years
				Quartz		Silcrete		Quartzite		Tuff		Volcanic				
				n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	n	Weight (g)	
Total				662	488.70	1,014	1,857.10	401	5,332.16	5,831	6,791.75	565	9,378.60	**8,529**[∫]	**23,884.01**	

* Spits below this depth were culturally sterile in most cases. OSL dating of these spits indicate that they were formed before the accepted period at which human occupation took place in Australia. Accordingly, dates obtained from these spits have not been included here.

[∫]Excludes 17 artefacts recovered from un-stratified locations.

Table 5

Spit	Tool Types												MNI[a]	Core and core fragments	Tool Inventory		Flake/tool ratio[d]	Flake/core ratio[e]	Breakage Rates (%)[f]	Average weight by artefact (g)[g]	Rank Sum[h]	Relative Mobility[h]
	Backed	Burin	Concave Scraper	Convex Scraper	Denticulate	End Scraper	Multi purpose	Nosed Scraper	Notch	Step Scraper	Straight Scraper	Utilised Flake			Richness[b]	Diversity[c]						
1													2	1	0.00 (23)	1.32 (6)	No data	2.00 (23)	0.20 (23)	0.84 (1)	76	14
2	2								1		2	3	57	10	0.88 (5)	1.16 (7)	7.13 (4)	5.70 (6)	1.72 (20)	1.66 (18)	60	9
3	7		1								2	3	72	25	1.44 (1)	1.01 (13)	5.54 (3)	2.88 (21)	3.27 (9)	2.10 (20)	67	12
4	6		2									4	65	16	1.33 (2)	0.93 (14)	5.42 (2)	4.06 (16)	2.95 (12)	1.08 (4)	50	3
5	5			1								5	59	13	1.22 (3)	1.04 (12)	5.36 (1)	4.54 (14)	2.94 (13)	1.24 (8)	51	4
6	2		1									1	38	10	0.44 (16)	0.67 (19)	9.50 (5)	3.80 (17)	1.59 (21)	1.49 (12)	90	21
7	2											3	54	12	0.55 (12)	1.49 (3)	10.80 (6)	4.50 (15)	1.86 (19)	2.28 (22)	77	15
8	2			1					1		1	3	90	32	0.88 (4)	0.8 (15)	11.25 (8)	2.81 (22)	3.16 (11)	3.32 (23)	83	20
9				1		1						5	77	15	0.77 (6)	1.56 (2)	11.00 (7)	5.13 (9)	3.23 (10)	1.74 (19)	53	6
10	1			1	1				1	2			77	11	0.66 (9)	0.69 (18)	12.83 (10)	7.00 (3)	2.73 (15)	1.42 (11)	66	11
11											1	1	59	12	0.22 (21)	0.69 (17)	29.50 (22)	4.92 (11)	2.87 (14)	1.10 (5)	90	22
12				1							1		57	16	0.22 (20)	1.33 (5)	28.50 (21)	3.56 (18)	2.53 (17)	1.62 (16)	97	23
13				2	1					1		2	68	20	0.66 (8)	1.04 (11)	11.33 (9)	3.40 (20)	3.71 (6)	1.53 (14)	68	13
14		1								2	1		105	18	0.44 (15)	1.1 (8)	26.25 (19)	5.83 (5)	5.41 (1)	1.12 (6)	54	8

15				1	1							1	79	16	0.33 (17)	0.69 (16)	26.33 (20)	4.94 (10)	3.62 (7)	1.25 (9)	79	16
16						2						2	72	11	0.44 (14)	1.05 (9)	18.00 (13)	6.55 (4)	4.63 (3)	1.29 (10)	53	7
17					2					1		2	98	20	0.55 (11)	1.56 (1)	19.60 (14)	4.90 (13)	4.15 (4)	1.63 (17)	60	10
18				2	1		1			1	1		99	18	0.66 (7)	1.04 (10)	16.50 (12)	5.50 (7)	4.82 (2)	1.53 (13)	51	5
19									1		1	2	88	12	0.44 (13)	1.33 (4)	22.00 (16)	7.33 (2)	4.01 (5)	0.92 (2)	42	2
20			1					1		1		2	75	9	0.55 (10)	No data	15.00 (11)	8.33 (1)	3.27 (8)	1.23 (7)	37	1
21												2	47	9	0.22 (19)	No data	23.50 (17)	5.22 (8)	2.57 (16)	2.18 (21)	81	17
22												2	49	10	0.22 (18)	No data	24.50 (18)	4.90 (12)	2.49 (18)	1.54 (15)	81	18
23												1	21	6	0.11 (22)	No data	21 (15)	3.5 (19)	1.40 (22)	1.01 (3)	81	19
Total	**27**	**1**	**5**	**10**	**6**	**3**	**1**	**1**	**4**	**8**	**10**	**44**	**1,508**	**322**								

[a]MNI includes complete, broken proximal and longitudinally snapped flakes only (after Hiscock, 2002) from PT 12-A(2) assemblage.

[b]Richness is number of tool types/log(sample size).

[c] Shannon-Weaver diversity index (H) using tool data presented in this table.

[d] Complete proximal and longitudinally snapped flakes divided by all tools.

[e] Complete proximal and longitudinally snapped flakes divided by all core and core fragments.

[f] Total number of broken flakes (including proximal and distal ends), excluding longitudinal breaks.

[g] Average mean weights are total spit weights divided by artefact numbers, excluding manuports. Manuports were generally large river cobbles (n=233), and significantly modified the average weights presented here.

[h] Higher values indicate greater mobility.

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Figure 1: Maps of: A) sites referred to in the text (1-Carpenter's Gap 1; 2- Narwala Gabarnmang; 3-Malakunanja II; 4- Nauwalabila 1; 5-Riwi; 6-Devil's Lair; 7-Cranebrook Terrace; 8-Bass Point; 9-SGCD 16; 10-KII Shaws Creek; 11-RTA-G1; 12-PT 12; 13-Lake Mungo; 14-Box Gully; 15-Point Ritchie; 16-Bend Road; 17-Keilor; 18-Jamisons Creek; 19-Regentville 1; 20-Windsor Museum); B) detail of sites in western Sydney (using same numerical codes); and C) detailed location of PT 12, -A and –B, and the potential extent of the sand dune system.
296x210mm (96 x 96 DPI)

Figure 2: Photograph of PT 12-A(1), a 25 m2 open area excavation located some 300 m from the edge of the ridge. Note the hearth feature near the scales, a date from which provided the only secure date for the upper archaeological assemblage. Also note the pebbly texture in the lower profile, a result of ironstone and manganese precipitation from an elevated water table. Scale=20cm increment.
327x219mm (300 x 300 DPI)

Figure 3: Photograph of PT 12-A(2), a 75m2 open area excavation on the deepest part of the deposit on the edge of the ridge. A main tributary of the Hawkesbury River is immediately downslope behind the trees in the background. In general, excavations reached 120 cm below surface, with one exploratory test pit being dug to 250 cm below surface. Scale=20cm increment.
327x219mm (300 x 300 DPI)

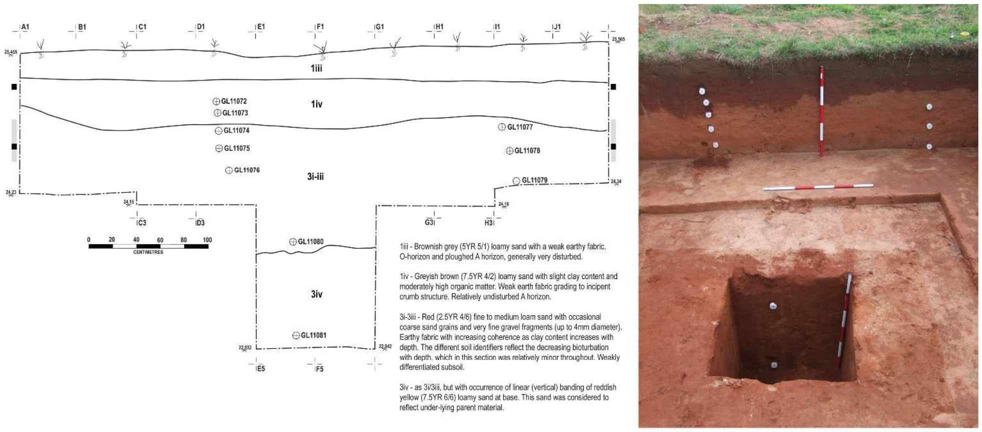

Figure 4: Photograph and simplified scaled drawing of PT 12-A(2), showing the location of OSL samples and main sedimentological units (descriptions after Williams et al., 2012). The main artefact concentrations are also presented adjacent the section showing both high (grey band) and peak (black square) numbers. Scale = 20 cm increment.
420x198mm (300 x 300 DPI)

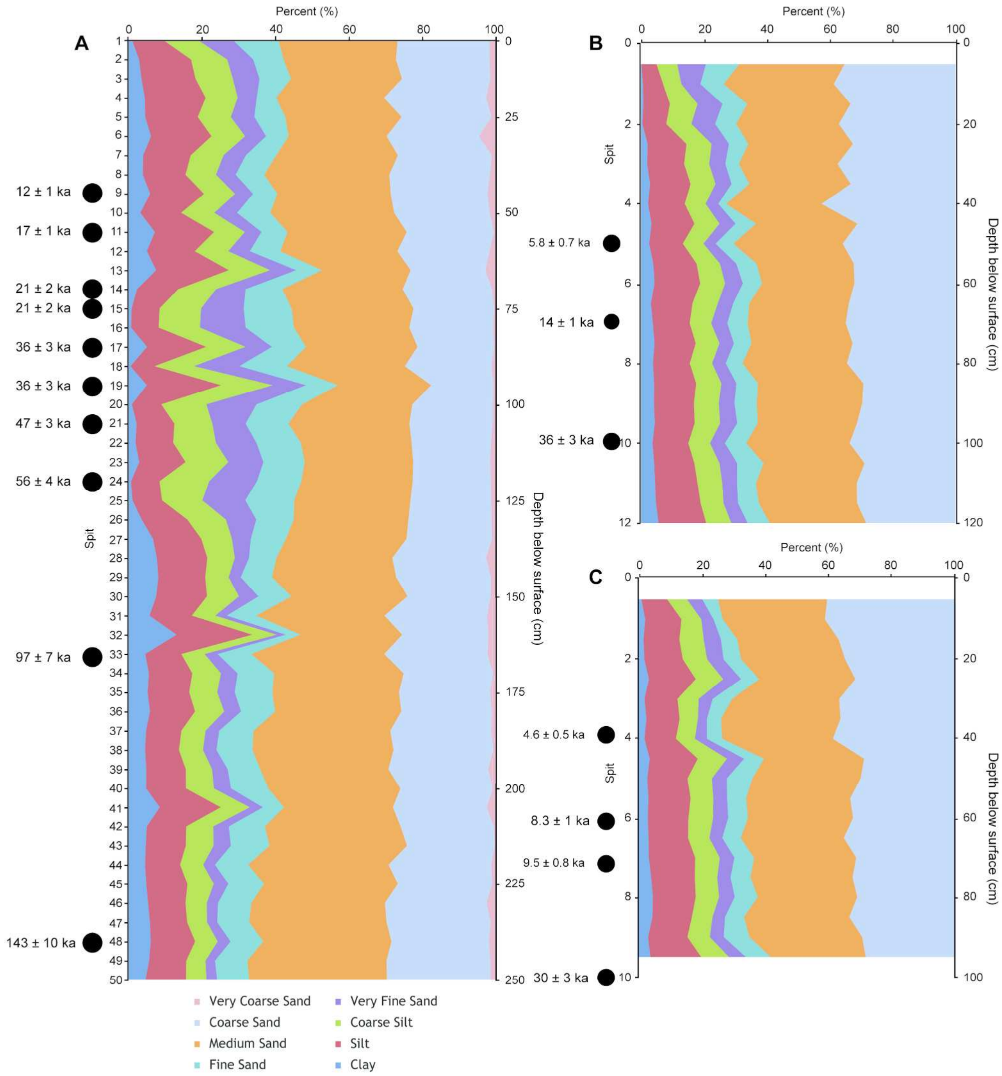

Figure 5: Particle size analysis of: A) PT12-A(2); B) PT 12-B, test pit 56; and C) PT 12-B, test pit 89. In relation to (A), soil samples were collected as discrete 1 cm samples at 5 cm intervals down the profile; for (B) and (C), contiguous bulk samples 5cm in size were collected down the profile. All samples were measured using a Malvern Mastersizer 2000®. Grain size definitions are presented after Gale and Hoare (1991). Note at PT-12A(2), the lowest samples are dominated by coarse grain size, suggestive of fluvial origins, with a trend towards finer material after 60ka, and especially through MIS 2 and 3. This latter period is considered to represent aeolian processes at work, and is further evident by the deposition of parts of the sand body at PT 12-B only in the last 30-40ka.
209x224mm (300 x 300 DPI)

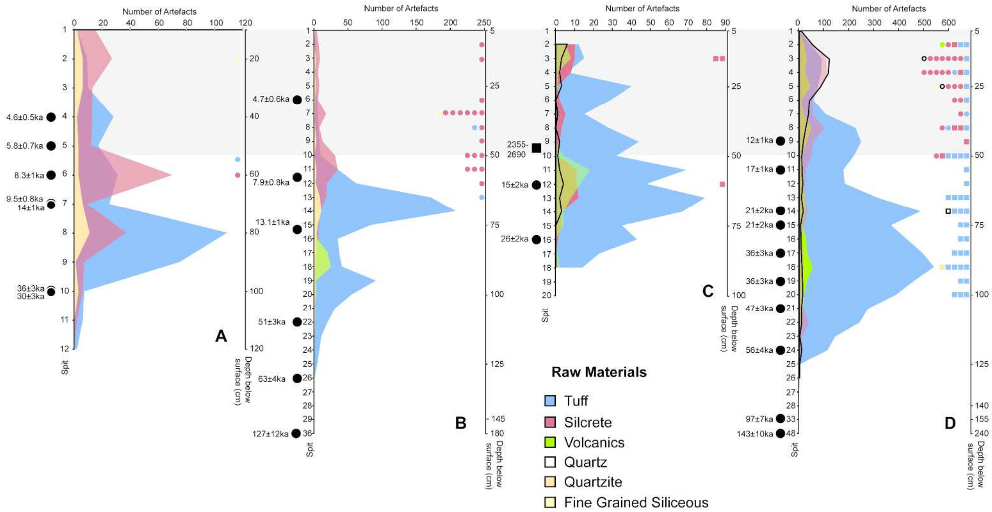

Figure 6: Summary diagram of selected artefact materials and OSL ages recovered from excavations at: A) PT 12-B (includes all artefactual material from across the 65 test pits excavated at this location); B) PT 12 (Williams et al., 2012); C) PT 12-A(1); and D) PT 12-A(2). OSL ages are presented as black circles. One radiocarbon date from an intrusive hearth is shown as a black square. Individual tools are presented as symbols to the right of the graphs: squares = scrapers, circles = backed artefacts. The generally disturbed plough zone is also shown as grey banding.
294x151mm (300 x 300 DPI)

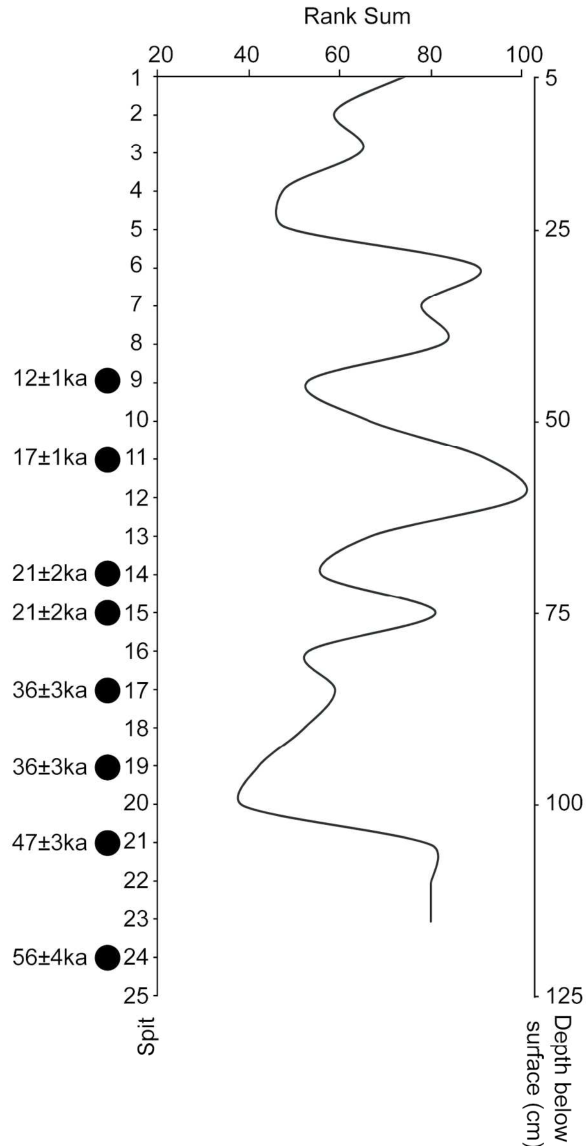

Figure 7: Relative mobility of the artefact assemblage of PT 12-A(2) after rank sum data in Table 5, and methods outlined in Smith (2006). Here, the higher the number, the greater the relative hunter-gatherer mobility.
115x216mm (300 x 300 DPI)