Williams, A N and Atkinson, F and Lau, M and Toms, Phillip (2014). *A glacial cryptic refuge in south-east Australia: human occupation and mobility from 36 000 years ago in the Sydney Basin, New South Wales.* **Journal of Quaternary Science, 29 (8), 735-748. ISSN 0267-8179**

Journal of Quaternary Science

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

3 Alan N. Williams[1,2], Fenella Atkinson[1], Michelle Lau[1], Phillip S. Toms[3]

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5 [1] Archaeological and Heritage Management Solutions Pty Ltd, 2/729 Elizabeth Street, Waterloo NSW

6 2017, Australia. E-mail: awilliams@ahms.com.au

7 [2] Fenner School of Environment and Society, The Australian National University, Canberra, ACT

8 0200, Australia.

9 [3] Luminescence Dating Laboratory, University of Gloucestershire, Swindon Road, Cheltenham, GL50
10 4AZ, United Kingdom

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12

13 **Abstract**

14 Excavations across a source-bordering dune overlooking the Hawkesbury River suggest an initial

15 occupation of the region by at least 36ka, with variable but uninterrupted use until the early Holocene;

16 following abandonment, the site was then re-occupied by ~3ka. Along with a handful of other sites,

17 the results provide the earliest reliable evidence of permanent regional populations within

18 southeastern Australia, and support a model in which early colonisers followed the coastal fringe with

19 forays along the main river systems. The evidence is consistent with Williams' (2013) demographic

20 model, which suggested low, but established regional populations prior to the Last Glacial Maximum

21 (LGM), a population nadir following the LGM, and increasing use of the region from ~12-8ka. The

22 site exhibits increased use at the onset and peak of the LGM, and provides an example of a cryptic

23 refuge as defined by Smith (2013). Specifically, changing artefact densities and attributes show the

24 site was used repeatedly, but for shorter periods through this time, and suggest it formed one of a

25 series of key localities in a point-to-point (rather than home-base) subsistence strategy. This strategy

26 was maintained until the site's abandonment in the early Holocene, despite changing population and

27 climatic conditions through the Terminal Pleistocene. The findings here demonstrate the importance

28 of the Hawkesbury River as a resource area for the early occupation and survival of Aboriginal people

29 over the last 46,000 years; and highlight its importance as a focus for future research.

30

31 **Keywords**

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

33

34 **1. Introduction**

35   The colonisation date of Australia is now conservatively established at least 46ka and possibly earlier

36   (O'Connell and Allen, 2012; Roberts et al., 1990). There are several archaeological sites across the

37   top end of Australia that had been occupied by this time, including Carpenters Gap 1, Narwarla

38   Gabarnmang, Malakunanja, Nauwalabila and Riwi (Balme, 2000; David et al., 2011; O'Connor,

39   1995; Roberts et al., 1994). Exploration of the continent by founding populations occurred quickly

40   with evidence of human activity in the southernmost parts of Australia by 40ka (e.g. Turney et al.,

41   2001). This first long phase (46-30ka) was brought to an end by climatic conditions during the Last

42   Glacial Maximum (LGM) and although occupation persisted in many regions, evidence is sparse and

43   populations may not have grown and consolidated again until the start of the Holocene (Williams,

44   2013). It is not until after the LGM that archaeological materials (*a priori* population) increase (e.g.

45   Hiscock, 2008; Smith, 2013). However, our understanding of when parts of Australia were

46   'permanently' occupied, or and the nature and mechanism of population movement across the country

47   is still poor.

48

49   Recently Williams et al. (2013) identified the Sydney Basin bioregion as a possible refugium during

50   and prior to the LGM, and a location in which early colonisation links between the north and south of

51   Australia may be found. However, despite over 50 years of research within the Sydney Basin,

52   evidence for pre-LGM and LGM occupation has been elusive. Overwhelmingly, sites appear to be of

53   (usually late) Holocene age, with only five archaeological sites showing evidence earlier than this:

54   Cranebrook Terrace containing artefacts dated to ~40ka (Nanson et al., 1987); Bass Point midden

55   with a basal deposit dated to ~17.5-7.7ka (Hughes and Djohadze, 1980); SGCD16 (Fal Brook Site), a

56   shallow open site with artefacts recovered in association with charcoal dated to ~34ka (Koettig,

57   1987); Shaws Creek KII rockshelter, which has basal ages of ~16ka (Kohen et al., 1984); RTA-G1, a

58   sand deposit adjacent the Parramatta River with a basal age of ~32ka (McDonald, 2008); and the

59   current site, PT 12 (Williams et al., 2012). Of these, several have significant credibility issues either

60   due to dating unsecure materials, or reproducibility.

61

62   In this paper, we present the results of compliance-based archaeological excavations on a ridgeline

63   overlooking the Hawkesbury River in northwest Sydney. Using results previously published in

64   Williams et al. (2012) and two new large-scale excavations, we demonstrate ongoing occupation of

65   the region between 36 and 8ka, and discuss the site's contribution to an understanding of the

66   colonisation patterns of Australia, and the nature of occupation during periods of significant climatic

67   deterioration.

68

69   2. Study Area

70   Between 2008-2013, Archaeological and Heritage Management Solutions Pty Ltd undertook

71   archaeological investigations of a large sand body, PT 12 (#45-5-3198), in Pitt Town, northwest

72   Sydney, in advance of development. PT 12 sand body is situated on the edge of a ridge line that

73   follows the Hawkesbury River and associated tributaries. Preliminary findings have been presented in

74   Williams et al. (2012), and here we provide results on two further excavations located within PT 12 to

75   the south (PT 12-A) and east (PT 12-B) of the original works (Figure 1).

76

77   The focus of this paper is on the works undertaken at PT 12-A, which consisted of a large salvage

78   excavation totalling $100m^2$ in two locations on the sand body. These two locations were selected

79   through the findings of geo-physical and gridded test excavations, and consisted of: (1) a shallow part

80   of the deposit 300 m from the edge of the ridge (of which $25m^2$ was excavated) (MGA 56

81   301237.81E, 6282132.28N) (Figure 2); and (2) the deepest part of the sand body on the crest of the

82   ridge overlooking the river (of which $75m^2$ was excavated) (MGA 56 301196.51E, 6282076.27N)

83   (Figure 3). All excavation was done by hand using 5 cm spits in contiguous 50 cm squares; all

84   material was wet sieved through a 3mm mesh. Soil and dating samples were recovered from the

85   sections of the completed excavations. Excavation continued until sterile deposit or the water-table

86   was reached, which varied between 110 and 250 cm below the surface. Further discussion on the

87   excavations can be found in AHMS (2012).

88

89   At PT 12-B, AHMS undertook test excavations in the form of a grid of 1 m^2 test pits distributed

90   across a ridge, back dunes and swales, slopes and alluvial flats adjacent to the river. All excavation

91   was done by hand using 10 cm spits in contiguous 50 cm squares; all material was wet-sieved through

92   a 5mm mesh. Soil and dating samples were recovered from the sections of the completed excavations.

93   Excavation continued until sterile deposit was reached at ~120 cm below the surface. The test pits

94   identified a continuation of the sand body along the entire ridgeline, and several foci of occupation.

95   Here, we only discuss two test pits in detail, namely pits 56 (MGA 56 302694.20E, 6283447.11N) and

96   89 (MGA 56 302494.17E, 6283547.22N), within which significant archaeological material was

97   recovered. Further discussion on the excavations can be found in AHMS (2011).

98

99   **3. The Excavations**

100

101   *3.1 Sedimentology and Artefact Deposition*

102

103   Williams et al. (2012) identified the sand body as a Kandosol soil profile (Isbell 2002) consisting of a

104   1 m deep fine to medium loamy sand with various inclusions and levels of bioturbation, overlying Pitt

105   Town Sands or Londonderry Clay (both considered to pre-date the Aboriginal colonisation of

106   Australia). The upper profile (<50cm) revealed extensive disturbance from past agricultural use, with

107   levels of bioturbation decreasing with depth. Archaeological material was generally found in the main

108   orange loamy sand unit beneath the topsoil at depths ranging between 35 and 100 cm below the

109   surface (Figure 4). The profile was largely homogenous, with no evidence of former land-surfaces or

110   other bedding. As a result, there was no clear indication of how the sand body formed (either via

111   fluvial or aeolian processes) nor how the included artefacts were deposited (i.e. were they *in situ* or

112   moved through vertical displacement from the surface).

113

114   Works at both PT 12-A and –B demonstrate that Williams et al.'s description is consistent across the

115   sand body, with some minor local variation. This is most evident in relation to depth, which ranges

116   from <90 cm to >250 cm; and colour, which can range from white (Figure 2) through to deep red

117   brown (Figure 3). The presence of ironstone nodules in places reflects either shallower parts of the

118   sand body or a higher watertable (Figure 2), and does not necessarily represent culturally sterile Pitt

119   Town Sands as previously thought.

120

121   Additional particle size and thin section information shows that the sand unit was deposited in glacial

122   arid conditions in Marine Isotope Stage (MIS) 6 (190-130ka). The high proportion of medium, coarse

123   and very coarse sand makes fluvial deposition the most likely explanation (Figure 5). However, since

124   Aboriginal colonisation, there is evidence of increasing fine materials in the profile, most notably

125   through the section corresponding to MIS 2 and 3, indicating that aeolian processes later came to

126   dominate. This is supported by the results of the investigations at PT12-B, that found swales and

127   smaller back-dunes extending several hundred metres from the ridge's edge, demonstrating that PT 12

128   was part of a larger dune field; several parts of which appear to have formed only in the last 30ka

129   (Figure 5).

130

131   These results reflect a highly active landscape in which wind-blown deposits continuously exposed

132   and buried land surfaces, especially during Aboriginal occupation of the region. We therefore believe

133   that archaeological materials could quite easily have been deposited on these temporary land surfaces

134   and then been relatively quickly buried, with little other evidence of the former surface. Opportunistic

135   conjoin analysis also indicated that movement of the majority of the artefactual material was generally

136   less than 10 cm through the profile, and sections of individual heat-fractured cobbles were frequently

137   found in close association (at PT 12-A). Vertical displacement from the surface (of the entire

138   assemblage at least) is considered an unlikely alternative given the amount of conjoins present,

139   combined with the tightly constrained chronology.

140

141   *3.2 Chronology*

142

143   In combination with Williams et al. (2012), 25 Optically Stimulated Luminescence ages and one

144   radiocarbon age have been obtained from the sand body, making it one of the most comprehensively

145   dated archaeological sites in the Sydney Basin (Tables 1 and 2; Figure 4). OSL samples were prepared

146 using standard procedures by the University of Gloucestershire. Dose equivalent to the natural

147 luminescence signal was estimated through the Single-Aliquot Regenerative-dose (SAR) protocol

148 (Murray and Wintle, 2000, 2003) using 12 multigrain 8 mm aliquots. For each sample, Dose

149 Recovery, Low and High Repeat-Regenerative doses, post-IR OSL (Duller 2003) and partial resetting

150 of OSL prior to burial (Bailey et al. 2003) were assessed. The rate of dose exposure was assessed

151 from each sample's radiochemistry (Adamiec and Aitken 1998) using a laboratory-based Ortec GEM-

152 S high purity Ge coaxial detector system, accounting for modulation forced by grain size (Mejdahl

153 1979) and present moisture content (Zimmerman 1971). Cosmogenic Dr values were calculated on

154 the basis of sample depth, geographical position and matrix density (Prescott and Hutton 1994)..

155

156 Of the 25 OSL ages, eight were considered to have analytical caveats (including partial bleaching,

157 over dispersion, feldspar contamination and/or a failed dose recovery test), and as such must be

158 treated with greater caution. The majority of these samples came from depths well beneath the

159 archaeological assemblage (e.g. GL11080) and are largely irrelevant to our analysis. A small number

160 of them came from the upper deposits (characterised by a heavily mixed plough soil), and we

161 similarly treat these ages with circumspection. The laboratory only identified one age that should be

162 rejected outright, GL10009 (see Williams et al., 2012 for further discussion).

163

164 The OSL chronology indicates that the lowest deposits of the PT 12 sand body generally dated to

165 >90ka, with the oldest age of ~143ka found at 250 cm below the surface in PT 12-A(2). The lower

166 deposits at PT 12-B were all dated to 36-30ka, and suggest some parts of the sand body formed later

167 than others. The lowest archaeological materials were associated with ages between ~63-51ka,

168 although the small number of artefacts at these depths probably indicate some minor vertical

169 displacement to these depths rather than *in situ* deposition (Figure 6). The lowest peak in material

170 (considered to reflect the first use of the region) comes from PT 12-A(2) and is bracketed by two

171 identical ages of 36±3ka; significant numbers of artefacts were found in the spits immediately beneath

172 this peak suggesting a date of initial occupation closer to 40ka may be more likely. Williams et al.

173 (2012) initially postulated that the lower peak of artefacts at PT 12 may have been in the order of

174 35ka, but rejected such a proposition due to the caveats associated with the ages. The findings at PT

175 12-A(2), demonstrate that the lower peak at PT 12 was indeed 35ka in age.

176

177 Following initial occupation at PT 12 and PT 12–A(2), there is a suite of ages through the artefact-

178 bearing deposits, ranging from 36ka through to 4.8ka (Figure 6). Two distinct assemblages were

179 evident in all of the excavations: A lower assemblage dominated by tuff and characterized as

180 Capertian (see below for terms) focused between ~26 and 8ka; and an upper assemblage dominated

181 by silcrete and characterized as Bondaian focused between 15 and 0ka, and primarily at <5ka. Using

182 age-depth models (polynomial second order) for each area, peaks in artefact numbers associated with

183   the lower assemblage are evident at 11ka at PT 12, 16.2ka and 11.6ka at PT 12-A(1), 21ka and 12ka

184   at PT 12-A(2), 26ka (test pit 89) and 19.5ka (test pit 56) at PT 12-B. Peaks in the upper assemblage

185   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

186   12-A(2); 8.3ka(test pit 56) and 5.8ka (test pit 89) in PT 12-B. Backed artefacts, one of the main

187   diagnostic tool types of the Bondaian technology, were recovered from deposits dating to as early as

188   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

189   initially considered to date to ~5.5ka (Williams et al. 2012), although the larger and less disturbed

190   assemblage recovered from PT 12-A(2) suggests an age closer to 2.5ka, which is more consistent with

191   wider archaeological literature (e.g. Attenbrow, 2004; Hiscock, 2008; Hiscock and Attenbrow, 2005).

192   A shift from Capertian style scrapers to backed artefacts is also evident at ~8.5ka in PT 12-A(2).

193

194   In general, radiocarbon dating proved unfeasible, since agricultural activities across the site included

195   regular burning of vegetation in the late 20th Century, and examination of the soil profile showed that

196   charcoal from this process had moved downwards. However, one date was obtained from a discrete

197   hearth dug into the sand body at PT 12-A(1), and provides the most reliable age of 2.3-2.6ka for the

198   upper assemblage. This correlates well with the date of the backed artefact proliferation at PT 12-A(2)

199   (Table 2).

200

201   *3.3 Lithics*

202

203   Across PT 12, PT12-A and PT 12–B, the artefacts could be divided into two broad horizons based on

204   assemblage composition and vertical location (Figure 6): 1) an upper horizon composed primarily of

205   silcrete and quartz artefacts, including backed artefacts; and 2) a lower horizon of amorphous pebble-

206   tools and manuports composed of tuff, with lesser occurrences of volcanic and quartzite materials.

207   This lower horizon had multiple peaks and troughs and probably represents a number of different

208   periods of occupation between 36 and 8ka. While the two horizons are considered to reflect quite

209   different temporal phases, there is rarely a physical gap between the two assemblages, and frequently

210   the two cross over. This is likely the result of some vertical displacement within the upper parts of the

211   sand body through bioturbation (tree roots and insect burrows were frequent) and the mixing of the

212   upper 40-50cm of the profile by ploughing. The shift between the two horizons, most evident in the

213   reduction in use of tuff, appears to have occurred by ~8-7ka. Williams et al. (2012) believed that this

214   age probably reflected the end of the Terminal Pleistocene occupation of the region, followed by a

215   hiatus in occupation until the late Holocene; further evidence presented here supports this view.

216

217   The assemblage from the lower horizon had features typically found in the Australian core tool and

218   scraper tradition (Hiscock and Attenbrow, 2005), also termed Capertian. This broad, pan-continental

219   category encompasses all Pleistocene and early Holocene assemblages and is defined by the

220   dominance of tuff (grey chert) and the presence of large, concave and nosed "scrapers, knives,

221   dentated saws and burins, with a few choppers, unspecialized cores, uniface pebble implements and

222   hammerstones" (McCarthy 1964:141). With specific reference to PT 12-A(2), where the majority of

223   the artefacts were recovered, the tools were dominated by large stepped, notched and concave

224   scrapers and composed primarily of tuff (Tables 4 and 5; Figure 6). For the most part, however,

225   artefact production was relatively simple, with a succession of flakes being struck from river pebbles

226   before one was selected for further reduction. The cores were mainly uni-directional, showing no

227   evidence of systematic core preparation, and a preference to produce and transport larger flakes

228   (Table 4). Flakes were typically larger and heavier in this horizon, although much more variable,

229   compared to the silcrete-dominated horizon above. The large numbers of small tuff flakes indicated

230   that retouching and re-sharpening of tools and the continued reduction of small cores occurred along

231   the ridgeline. Few artefacts retained cortex, suggesting that primary reduction was occurring

232   elsewhere. However, the main raw material source is thought to be cobbles from the nearby river.

233   This is supported by the discovery of numbers of large river cobbles (n=223 at PT 12-A) generally in

234   the lower depths. The unworked cobbles frequently had evidence of burning and heat-fracturing,

235   indicative of use as heat retainers or hearth-stones.

236

237   Artefact breakage rates were high throughout PT 12-A(2) (n=6,045; 71%), especially between spits

238   14-19 (~36-21ka) at the onset and peak of the LGM. This has been used to indicate site-use intensity

239   (greater trampling equating to more damage to the assemblage). However, when applying methods

240   outlined in Smith (2006) in which artefact attributes are assigned a mobility ranking (e.g. greater tool

241   diversity equating to lower mobility or heavier average weight suggestive of higher mobility), the

242   assemblage suggests hunter-gatherer use of the area reflected repeated short term occupation, rather

243   than long term base camps, through this period (Table 5; Figure 7).

244

245   McCarthy (1964:143) defines the Bondaian culture of the Sydney region as "having trimmed blocks, a

246   few elouera, burins, flake fabricators, scrapers of many kinds, a wide range of geometrical microliths,

247   and the Bondi point in large numbers; it marks the beginning of gum hafting of knapped implements

248   and the appearance of the ground edge in eastern New South Wales." Attenbrow (2010:153-158)

249   expands on this definition by noting that implements and associated debitage are much smaller in

250   average size and weight than those from earlier assemblages, and that there is an increase in the use of

251   silcrete and quartz coupled with use of the bipolar percussive technique over time (especially from 3-

252   0ka). At PT 12-A(2), there is a significant shift to the use of silcrete and quartz combined with a

253   greater diversity in the raw material types used in the upper spits (1-11). The complete flakes and

254   flake scars on cores are more elongated in form than in the lower assemblage. These characteristics

255   are indicative of a more systematic core reduction, associated with the manufacture of backed

256   implements (Bondi points or geometric microlithics) that are generally made on small, light elongated

257   flakes (Tables 4 and 5). The absence of large complete flakes of silcrete (>25mm) indicates that

258   silcrete was obtained from further away than the tuff, most likely from outcrops in the

259   Riverstone/Plumpton Ridge area, some 12 km to the southwest of PT 12 (Corkhill, 1999). Cortex is

260   often absent, which similarly suggests transport from some distance and where present it is often

261   dominated by water-rolled characteristics. Increasing evidence of primary silcrete outcrop exploitation

262   is present in the upper deposits. Again there are a large number of broken flakes in the assemblage,

263   but fewer than in the lower assemblage; a larger number of these breaks are probably a result of the

264   more complex and delicate manufacturing techniques required for backed artefacts, rather than

265   trampling. Decreasing relative mobility through this time (Table 5; Figure 7), along with increased

266   discard rates (Table 4), indicates increasing and more prolonged use of this region, perhaps akin to a

267   base camp, in the late Holocene, despite overall artefact numbers being lower than in the earlier

268   horizon.

269

270   There were significant issues with the findings and interpretation of the upper assemblage at PT 12

271   based on the level of disturbance of the deposit and caveats associated with the OSL ages. Williams et

272   al. (2012) believed that there was a hiatus between the two assemblages, but this could not be proven

273   and tentative conclusions were made that the upper assemblage was an unusually early Bondaian

274   industry. The upper assemblage at PT 12-A is larger and appears less disturbed. Here, we find that a

275   proliferation of backed artefacts and the increasing use of quartz both occur at ~2.5ka (spits 3 and 4),

276   and in combination with a hearth feature in PT 12-A(1) dating to ~2.3ka, conclude that the upper

277   assemblage is likely of middle or late Bondaian age (3-0ka). We believe that a hiatus between the two

278   assemblages is likely, with an abandonment of the site between ~8 and 3ka.

279

280   The results of the excavations at PT 12-A and -B correlate closely with the findings from PT 12. In

281   total, the three excavations at PT 12, PT12-A and PT12–B have recovered 11,402 stone artefacts, of

282   which 8,544 (75%) come from PT 12-A(2) (Table 3). Artefact densities varied from as low as $5/m^2$ in

283   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

284   within the main fore-dune, average densities were generally $>35/m^2$. Based on roadside sections and

285   aerial photography, the sand body appears to run continuously from PT 12-A to PT 12-B (a distance

286   of 3km), and is consistently at least 100-150 m wide (Figure 1). Using this area and the range of

287   artefact densities outlined above, potentially between 2.3 and 94 million artefacts may be present

288   within the sand body. While speculative, using Hayden's (1977) artefact production rates of 150

289   artefacts per year for a nuclear family in the western deserts, this could equate to between 1 and 22

290   such families annually using the region between 36-8ka.

291

292   *3.4 Summary of the Excavation Findings*

293

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

299

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

311

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

323

4. Discussion

325 There still remains controversy surrounding how rapidly hunter-gatherer populations increased
326 following initial colonisation of the continent. Birdsell (1957) was the first to propose a model for
327 saturation of the prehistoric continent by a hunter-gatherer population that rapidly achieved
328 ethnographic population densities. Using modern analogues, he argued that a small founding
329 population could have colonised the continent in only 2,000 years - populations 'budding off' into

330   new areas as carrying capacity was reached. Conversely, Beaton (1983), Lourandos (1983, 1997) and

331   others proposed an alternative model, suggesting populations were consistently low in the Pleistocene,

332   before exponentially expanding in the mid- to late Holocene. More recently, Williams (2013)

333   explored these ideas using radiocarbon data from archaeological sites across Australia. He found that

334   populations remained low in the Pleistocene (but at levels significantly higher than previously thought

335   and comparable with the early Holocene), before increasing in a step-wise manner from 12 to 0.5ka.

336   Spatially, archaeological evidence from the southern parts of Australia supports this model, with only

337   two sites reliably exhibiting visitation prior to 40ka, namely Devil's Lair in southwest WA, and the

338   burials at Lake Mungo (LMIII being dated to 42±3ka) (Bowler et al., 2003). Other less reliable

339   findings also include a single flake in pre-40ka deposits at Box Gully (Richards et al., 2007), a

340   possible midden at Point Ritchie dated to 49-43ka (Sherwood et al., 1994), and five artefacts

341   recovered from parts of the Cranebrook Terrace dated to >42ka (Nanson et al., 1987).

342

343   In contrast to Williams' model, however, there is little evidence of increasing populations prior to the

344   LGM with a pattern of ephemeral activity and visitation persisting until the Terminal Pleistocene. For

345   example, excavations at Bend Road, an open site near Keysborough, recovered only 17 artefacts from

346   deposits dating to before 30ka (Hewitt and Allen, 2010); Koettig (1987) recovered 49 artefacts

347   associated with a hearth dated to 40-37ka adjacent to Fal Brook, a tributary of the Hunter River; a

348   short episode of hearth features, faunal remains and 14 artefacts were recovered from a lunette

349   adjacent to Box Gully deposited between 32 and 26ka; and remains of hearths and midden materials

350   at Keilor deposited before 31ka (Gallus, 1976). Only the Willandra Lakes system and parts of

351   southwest and central Tasmania (from ~ 35ka) show more extensive occupation and run counter to

352   this view (e.g. Balme and Hope, 1990; Webb et al., 2006; Smith et al., 2008; Cosgrove, 1995; Stern

353   and Allen, 1996; Allen, 1996). Through the findings at PT 12, we can now demonstrate that the

354   Hawkesbury River corridor in western Sydney was also a likely area of prolonged occupation prior to

355   the onset of the LGM. The ongoing and intense use of PT 12-A(2), along with low relative mobility,

356   prior to the LGM suggests a permanent regional population in the Sydney Basin (rather than

357   occasional visitation), and lends significant support to a more substantial occupation in the southeast

358   corner of Australia by this time. These levels of occupation and activity were maintained, if not

359   enlarged, through the Terminal Pleistocene.

360

361   The focus of occupation on the PT 12 sand body by this time is not unexpected, as the site is

362   surrounded by a range of biomes (e.g. mountains, rolling hills, incised creek systems, etc) and located

363   on a fluvial system that probably had permanent flow from increased summer snow melt of glacial ice

364   in the upper reaches of the catchment (Williams et al. 2012, 2013). More locally at Pitt Town, the

365   entrenched river had a number of useful resources, including a wide range of stone raw materials, as

366   well as food and wood materials likely associated with a large river system. In addition, colonization

367   models have previously indicated that movement and expansion probably followed the coastal fringe

368   (Bowdler, 1977) and large water-courses into the interior of the continent (White and O'Connell,

369   1982). The Hawkesbury River fulfils these conditions providing easy access from the coast to >60km

370   inland, even further when considering Pleistocene low sea-stand; the site was also largely

371   unapproachable from the west due to the Blue Mountains. The presence of SGCD 16 near the Hunter

372   River suggests other nearby river systems may have been used in a similar fashion prior to the LGM.

373

374   The LGM in Australia was a two-step period of significant cooling and increased aridity beginning

375   ~30ka and peaking between ~23-18ka (e.g. Petherick et al., 2011; Reeves et al. 2013; Williams et

376   al., 2009). Human response to the LGM has formed a persistent theme in Australian archaeological

377   research and interpretations for over 30 years (e.g. Veth, 1989a, 1993; O'Connor et al., 1993; Smith,

378   2013). Research has primarily focused on the arid zone and suggested the importance of refugia –

379   well-watered ranges and major riverine systems – and the abandonment of large tracts of desert and

380   marginal country (Lampert and Hughes, 1987; Smith, 1988; Hiscock, 1988; Veth, 1989b). Using geo-

381   spatial techniques, Williams et al. (2013) re-explored these ideas at a continental scale, and similarly

382   identified a number of broad-scale refugia during the LGM, including the temperate Sydney Basin.

383   The findings at PT 12-A(2) showing increased artefact numbers at and immediately following the

384   LGM supporting the identification of the Hawkesbury River as a refuge.

385

386   While previous research has focused on the broad-scale nature of hunter-gatherer behavior at the

387   LGM, Smith (2013) undertook detailed review of a number of individual refuges, and considered that

388   abandonment of entire regions was unlikely. Rather, he considered archaeological evidence more

389   accurately reflected cryptic refugia – a thinning out of populations across the country into pockets of

390   micro-habitat. Specifically, he found that the classic ethnographic refuges (the home-base model)

391   were not supported, but rather a point-to-point system of subsistence in which increasing residential

392   mobility across key resource localities with limited season dispersal into back country, was more

393   realistic. While Smith's work was focused in the arid zone, the results of PT 12-A(2) very much

394   support the point-to-point model being applicable for temperate biomes. Our results show that at the

395   onset of the LGM, both artefact numbers and relative mobility increase (Table 5, Figure 7), which

396   strongly suggests the locality was used more intensely but not as a base-camp, rather for more

397   frequent shorter visits. During the actual peak of the LGM (spit 14), relative mobility decreases

398   slightly (and artefact diversity increases slightly) indicating that PT 12 may have formed a *key* locality

399   in a network of sites or points used by hunter-gatherers through this period - perhaps used for slightly

400   longer than at other times in the late Pleistocene. This pattern is, however, brief, with high relative

401   mobility evident in the spits immediately above the LGM. Currently, no other points in this system

402   have been discovered, although archaeological deposits found at the Windsor Museum (Williams et

403   al., 2012), 5km away, and the banks of the Parramatta River (McDonald, 2008), 27km away, are old

404 enough to form other possible nodes; other currently un-investigated ridge-lines along the
405 Hawkesbury River are also strong possibilities.

406

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

418

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

430

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

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

444

445 **5. Conclusion**

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

456

457 Recent studies by Williams et al. (2013) postulated that the Sydney Basin may have been a refugium
458 during the onset and peak of the LGM, primarily due to the availability of permanent water from
459 increased snow melt of glacial ice in the Blue Mountains and Australian Alps. Results at PT 12
460 indicate this is at least partially correct, demonstrating a focus of activity and use through this period.
461 In addition, we undertook further exploration on the nature of the refuge, based on work by Smith
462 (2013). Specifically, we believe that the greater number of artefacts in combination with inferred high
463 relative mobility through this period suggest that PT 12 formed a cryptic refuge - one of a series of
464 nodes within a point-to-point subsistence system, in which key localities were used as part of a
465 network by highly residentially mobile hunter-gatherers. No other LGM archaeological sites that may
466 form part of this point-to-point strategy have yet been identified in the Sydney Basin, although other
467 parts of the Hawkesbury River riparian corridor are a possibility. This subsistence strategy appears to
468 have been maintained throughout the Terminal Pleistocene, although the period immediately after the
469 LGM shows significant reduction in Aboriginal populations. A pulse of occupation is evident between
470 ~12 and 8ka, and also appears to be based on the same point-to-point system, the reasons for which
471 are unclear. We speculate that this may have been the result of increasing population pressure in the
472 region following sea-level rise and inundation of the coastal fringe, and a return to resource stress
473 behaviours.

474

475 The final phase of the site is heavily disturbed, but we have greater confidence in an abandonment of
476 the region in the mid Holocene, before re-occupation in the last few thousand years. The reason for

477 the abandonment remains unclear, but may reflect the loss of access to stone raw materials on this

478 section of the Hawkesbury at around this time due to river aggradation, leading to a re-organisation of

479 settlement patterns. Occupation of several sites further upstream, near currently exposed river gravels,

480 appears to begin from ~8ka.

481

482 Finally, we wish to highlight the importance of the Hawkesbury River corridor as a new area within

483 which to focus exploration of early Aboriginal occupation of Australia. This should be a high priority

484 area for researchers because the banks of the Hawkesbury River are being rapidly developed, and sites

485 such as PT 12 are becoming increasingly rare. Local and State government should also consider long-

486 term planning that ensures representative samples of the Pleistocene dune landforms on the fringe of

487 the Hawkesbury River are retained due to their rarity, cultural importance to the Aboriginal

488 community, and significant archaeological value. Key future research should focus on further

489 verification of the results from the PT 12 sand body at other areas along the riparian corridor; a

490 greater exploration of the last phase of Terminal Pleistocene occupation; and identification of areas

491 where surface disturbance may be low to allow greater understanding of the latest phase of

492 occupation.

493

494 **Acknowledgements**

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750 **Tables**

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

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

753 Table 3. Summary of the lithic data collected from PT 12, -A and –B. Both raw counts and

754 percentages (expressed in brackets) are presented for a range of diagnostic features and raw material

755 types.

756 Table 4. Summary of main raw material types from PT 12-A(2) by both raw counts (n) and weight

757 (g). Data are presented by spit, each of which are given an interpolated age range and length in years

758 based on the OSL chronology and a second order polynomial age depth model of GL11072 – 11081,

759 and assuming no disconformities.

760 Table 5. Index of relative mobility based on the PT 12-A(2) assemblage using methods after Smith

761 (2006). Each artefact indices has been assigned a rank of between 1 and 23 (presented in brackets),

762 with the greater the number reflecting higher mobility. Each of the individual rankings are then

763 summed together to form a rank sum, which is used to provide an overall indication of relatively

764 mobility by spit.

765

766 **Figures**

767 Figure 1: Maps of: A) sites referred to in the text (1-Carpenter's Gap 1; 2- Narwala Gabarnmang; 3-

768 Malakunanja II; 4- Nauwalabila 1; 5-Riwi; 6-Devil's Lair; 7-Cranebrook Terrace; 8-Bass Point; 9-

769 SGCD 16; 10-KII Shaws Creek; 11-RTA-G1; 12-PT 12; 13-Lake Mungo; 14-Box Gully; 15-Point

770 Ritchie; 16-Bend Road; 17-Keilor; 18-Jamisons Creek; 19-Regentville 1; 20-Windsor Museum); B)

771 detail of sites in western Sydney (using same numerical codes); and C) detailed location of PT 12, -A

772 and –B, and the potential extent of the sand dune system.

773 Figure 2: Photograph of PT 12-A(1), a 25 m^2 open area excavation located some 300 m from the edge

774 of the ridge. Note the hearth feature near the scales, a date from which provided the only secure date

775 for the upper archaeological assemblage. Also note the pebbly texture in the lower profile, a result of

776 ironstone and manganese precipitation from an elevated water table. Scale=20cm increment.

777 Figure 3: Photograph of PT 12-A(2), a 75m^2 open area excavation on the deepest part of the deposit

778 on the edge of the ridge. A main tributary of the Hawkesbury River is immediately downslope behind

779 the trees in the background. In general, excavations reached 120 cm below surface, with one

780 exploratory test pit being dug to 250 cm below surface. Scale=20cm increment.

781 Figure 4: Photograph and simplified scaled drawing of PT 12-A(2), showing the location of OSL

782 samples and main sedimentological units (descriptions after Williams et al., 2012). The main artefact

783 concentrations are also presented adjacent the section showing both high (grey band) and peak (black

784 square) numbers. Scale = 20 cm increment.

785 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.

786 In relation to (A), soil samples were collected as discrete 1 cm samples at 5 cm intervals down the

787 profile; for (B) and (C), contiguous bulk samples 5cm in size were collected down the profile. All

788 samples were measured using a Malvern Mastersizer 2000®. Grain size definitions are presented after

789   Gale and Hoare (1991). Note at PT-12A(2), the lowest samples are dominated by coarse grain size,

790   suggestive of fluvial origins, with a trend towards finer material after 60ka, and especially through

791   MIS 2 and 3. This latter period is considered to represent aeolian processes at work, and is further

792   evident by the deposition of parts of the sand body at PT 12-B only in the last 30-40ka.

793   Figure 6: Summary diagram of selected artefact materials and OSL ages recovered from excavations

794   at: A) PT 12-B (includes all artefactual material from across the 65 test pits excavated at this

795   location); B) PT 12 (Williams et al., 2012); C) PT 12-A(1); and D) PT 12-A(2). OSL ages are

796   presented as black circles. One radiocarbon date from an intrusive hearth is shown as a black square.

797   Individual tools are presented as symbols to the right of the graphs: squares = scrapers, circles =

798   backed artefacts. The generally disturbed plough zone is also shown as grey banding.

799   Figure 7: Relative mobility of the artefact assemblage of PT 12-A(2) after rank sum data in Table 5,

800   and methods outlined in Smith (2006). Here, the higher the number, the greater the relative hunter-

801   gatherer mobility.

1　**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.

$^{\Pi}$ 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	$\partial13C$	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.

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12   **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)

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16   **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)	Quartz n	Quartz Weight (g)	Silcrete n	Silcrete Weight (g)	Quartzite n	Quartzite Weight (g)	Tuff n	Tuff Weight (g)	Volcanic n	Volcanic Weight (g)	Assemblage Total n	Assemblage Total Weight (g)	Total number of artefacts/100years
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.

21 **Table 5**

Spit	Backed	Burin	Concave Scraper	Convex Scraper	Denticulate	End Scraper	Multi purpose	Nosed Scraper	Notch	Step Scraper	Straight Scraper	Utilised Flake	MNI[a]	Core and core fragments	Richness[b]	Diversity[c]	Flake/tool ratio[d]	Flake/core ratio[e]	Breakage Rates (%)[f]	Average weight by artefact (g)[g]	Rank Sum[h]	Relative Mobility[h]
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)

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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)

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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.
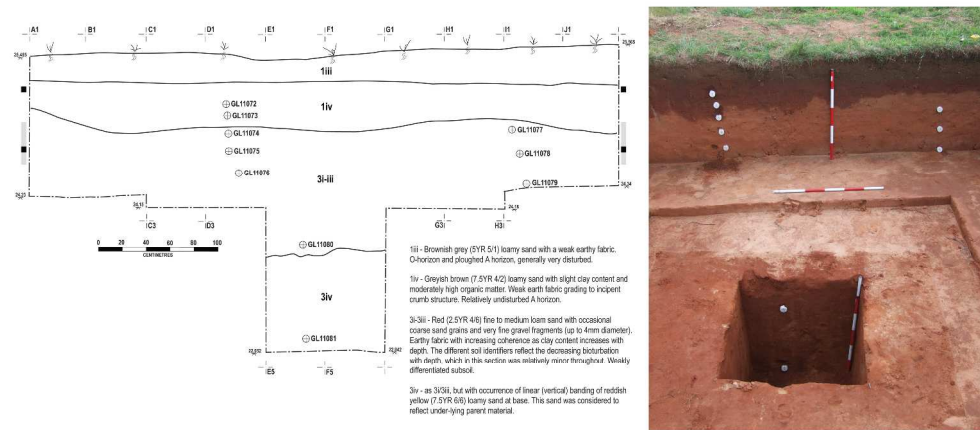327x219mm (300 x 300 DPI)

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)

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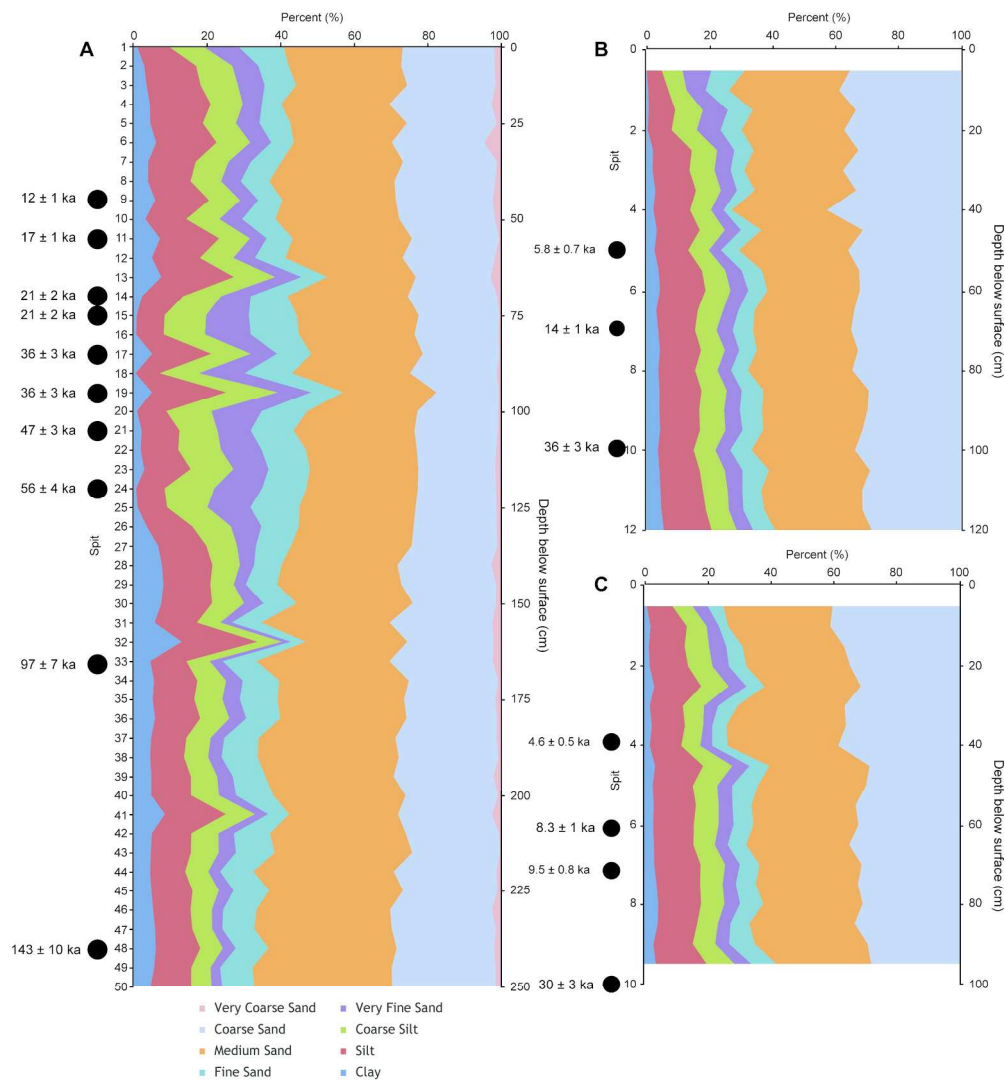49
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Figure 5: Particle size analysis of: A) PT12-A(2); B) PT 12-B, test pit 56; and C) PT 12-B, test pit 89. In relation to (A), soil samples were collected as discrete 1 cm samples at 5 cm intervals down the profile; for (B) and (C), contiguous bulk 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.
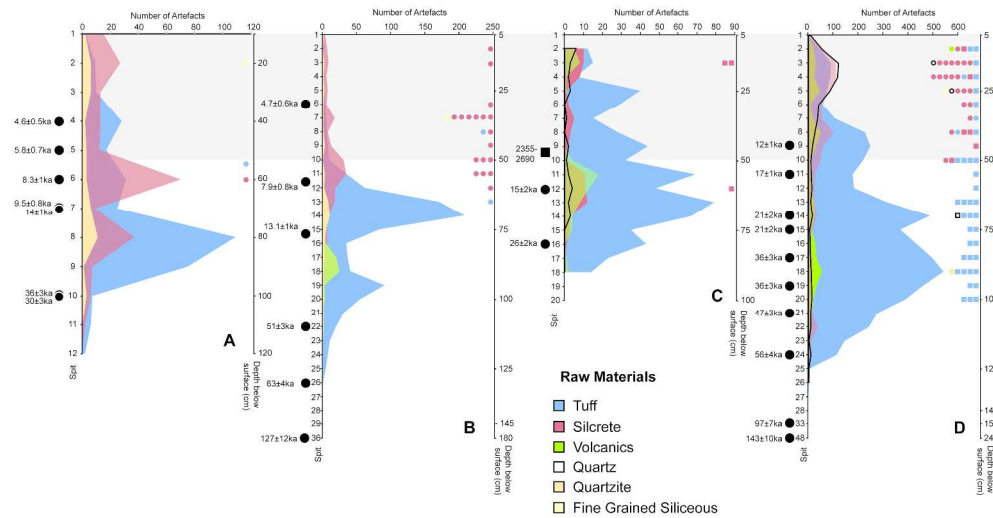209x224mm (300 x 300 DPI)

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)

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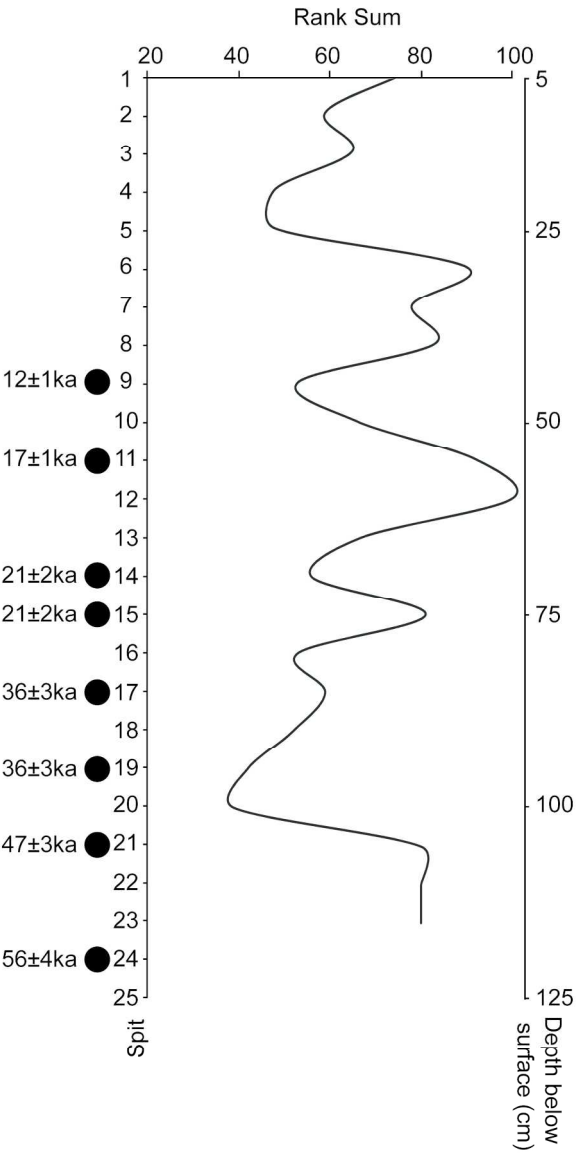51
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Figure 7: Relative mobility of the artefact assemblage of PT 12-A(2) after rank sum data in Table 5, and methods outlined in Smith (2006). Here, the higher the number, the greater the relative hunter-gatherer mobility.
115x216mm (300 x 300 DPI)