Archaeology in Oceania

Archaeology in Oceania, Vol. 00 (2024): 1–13
DOI: 10.1002/arco.5313

First Nations pre-LGM ochre processing in Parramatta, NSW, Australia

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ABSTRACT

Previous archaeological evidence and published analysis has suggested that ochre was first used in the Sydney Basin around 9000 years ago, and that the Parramatta region may not have been occupied by First Nations peoples before ∼14 ka. We present new evidence which firmly places both events before the Last Glacial Maximum (LGM). Multiple ochre fragments, two with microscopically visible evidence of anthropogenic grinding, were recovered from the George Street Gatehouse site within the Parramatta Sand Body (PSB) at Parramatta. The ground ochre was associated with a pit feature buried within the PSB and dated by optically stimulated luminescence (OSL) between ∼35 and 30 ka. This find is the earliest evidence for ochre processing in the Sydney Basin by some 25000 years. A previous model for the region had proposed that occupation prior to and during the LGM was focussed on the Hawkesbury-Nepean River corridor as a refugium, with only equivocal evidence of occupation prior to ∼14 ka at Parramatta (Williams et al., 2021). We propose that the Parramatta River could also have acted as a refugium for people moving through and occupying the now-drowned Pleistocene coastal zone; and that those people used ochre in their symbolic expressions.

Keywords: Ground ochre, use wear, pre-LGM, Aboriginal archaeology, Parramatta Sand Body

RÉSUMÉ

Des preuves archéologiques ainsi que des analyses publiées par le passé, suggéraient que l'ocre avait été utilisée pour la première fois dans le bassin de Sydney il y a environ 9000 ans, et que la région de Parramatta n'avait peut-être pas été occupée par les peuples des Premières Nations avant environ 14000 ans. Nous présentons de nouvelles preuves qui placent fermement ces deux événements avant le Dernier Maximum Glaciaire (DMG). Plusieurs fragments d'ocre, dont deux présentant des preuves microscopiques apparentes de broyage anthropique, ont été récupérés sur le site de George Street Gatehouse au sein du dépôt de sable de Parramatta. L'ocre moulue était associée à une fosse enfouie dans le sable qui a été datée par luminescence optiquement stimulée entre ∼35000 et 30000 ans. Cette découverte constitue la première preuve de la transformation de l'ocre dans le bassin de Sydney, datant d'environ 25000 ans. Un précédent modèle pour la région avait suggéré que l'occupation avant et pendant le maximum de la dernière période glaciaire se concentrait autour du couloir fluvial de la rivière Hawkesbury-Nepean, notamment pour ses qualités de refuge, avec seulement quelques preuves équivoques d'occupation avant ∼14000 ans à Parramatta (Williams et al., 2021). Nous proposons que le fleuve Parramatta aurait également pu servir de refuge aux personnes traversant et occupant la zone côtière du Pléistocène, aujourd'hui submergée; et que ces gens utilisaient l'ocre dans leurs expressions symboliques.

Mots-clés: Ocre moulu, traces d'usures, pré-DMG, archéologie Aborigène, dépôt de sable de Parramatta

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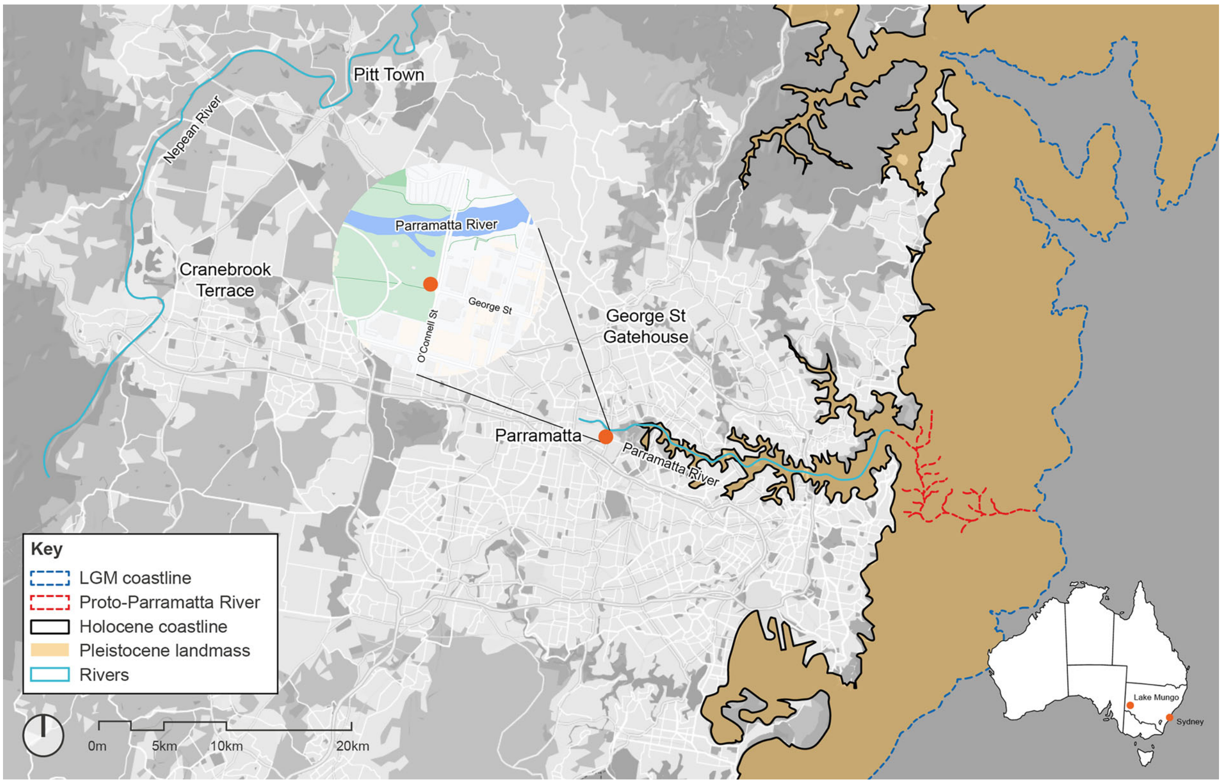
INTRODUCTION

An archaeological excavation in Parramatta, NSW, led to the discovery of ground ochre associated with a pit feature within Aeolian sediments. The deposits pre-date the Last Glacial Maximum (LGM), and the work raises multiple considerations and implications for First Nations occupation of the Greater Sydney Region before the LGM.

We detail the archaeological work, then consider, in turn, the geomorphological processes by which the ochre became buried in the sediments, the likely age of the ochre, the identification of evidence of grinding on the ochre, and the known antiquity of ochre use by people in the Greater Sydney Region. An examination and comment on existing Pleistocene occupation models is provided.

Figure 1. George Street Gatehouse, located in Parramatta, Sydney, NSW. Showing other locations identified in the text. The position of the LGM coastline and proto-Parramatta River at ~20 ka is after Albani et al., 2015, fig. 3.



George street gatehouse in Parramatta Park—Methods and results

George Street Gatehouse (GSG) is located on a terrace overlooking Parramatta River at Parramatta (Figure 1). Works associated with the GSG were part of a larger Aboriginal and historical archaeology project in the Gardens Precinct of Government House for Parramatta Parks Trust. Excavations at the GSG site were preceded by test excavations which are reported elsewhere (GML, 2015). The following information relates specifically to the small open area excavation during which the ochre was encountered.

Archaeological excavation methods

Following the test excavation program, construction works associated with the GSG required further subsurface excavation for a new service trench. This location had not been subject to test excavation. This represented an opportunity to investigate the highest location/landform inside the Gardens Precinct.

The excavation area was gridded into 1m × 1m excavation squares (squares 1–4) (Figure 2), with the extent and depth of archaeological excavation determined by the impact depth for the installation of services. Post-1788 activities in this area had mixed the uppermost portion of the Parramatta Sand Body (PSB) with historical topsoil—a common occurrence in Parramatta. This layer was 250 mm deep and referred to as "historical mixed topsoil" (Figure 3). At GSG we estimate that between 500 and 1000 years of accumulated PSB could have been lost, mixed and/or redeposited by modern land use.

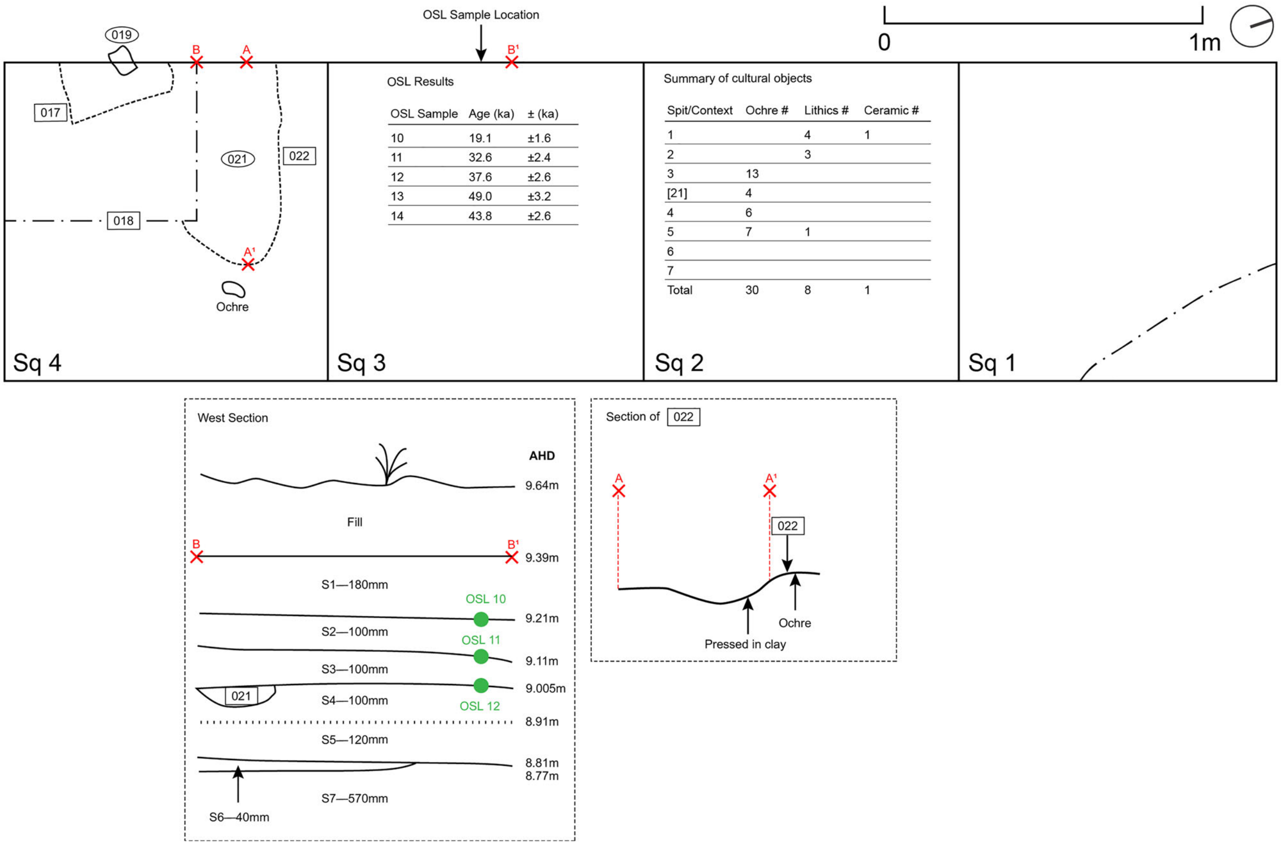
The excavation of PSB horizons with archaeological deposits was undertaken in six spits below the topsoil horizon (Figure 3). Spit 1 was intact, homogeneous PSB, albeit with roots and evidence of bioturbation (visible in Figure 3). Spit 1 (Australian Height Datum [AHD] top 9.39 m, 180 mm deep spit) was excavated until a uniform, predominantly undisturbed horizon was reached (the top of spit 2). Spit 2 onwards (100mm each) exhibited minimal disturbance from roots or bioturbation. No historical period (post-1788) artefacts were recovered below spit 1.

Hand excavation ceased at the end of S5/S6 (AHD 8.77 m to 8.81 m), the point where PSB characteristics changed and where interpretation of the PSB characteristics indicated no further Aboriginal archaeological deposits would be present. From this point a machine was used to remove the PSB to a final depth of AHD 8.20 m (spit 7). Spits 1 through 7 were wet sieved through a 3 mm mesh; spits 6 and 7 contained no cultural material (Figure 2 and Table 1). Spit 8 represented the end of the excavation.

Archaeological outcomes

A total of 39 Aboriginal cultural objects (Table 1, Figures 2–6) and one Aboriginal cultural feature were identified (Figures 2 and 4).

Figure 2. Upper the excavation trench (4x1 m), showing the excavation squares (Sq1 to Sq4). Sq4: cut for the ochre processing pit (context [22]). Sq3: OSL sample location in the western section. The two tables provide a summary of OSL results and the cultural objects by spit/context. Sq1 shows the base of a service cut in the northeast corner. Lower left: section profile for the trench's west face between squares 3 and 4 (with depths AHD, excavation spit depths and boundaries and the upper three OSL sample points). Lower, middle: section profile of the ochre pit.



Within square 4, 40 mm to 50 mm below the spit 2/3 interface (therefore intra-spit 3), the upper cut (context [22]) of a pit feature was identified. The cut was recorded and the feature's fill [21] was excavated (Figures 2 and 4). The feature was interpreted as an ochre heating or processing pit, measuring ~680 mm (east to west) and ~280 mm (north to south), by (maximum) 140 mm deep. Part of the feature extended outside the permissible excavation zone and remains unexcavated. We estimate the feature had total dimensions of ~800 mm by ~400 mm, by up to 140 mm deep.

The edges of the feature's cut presented a "dish" shape. A remnant surface of fired and hardened clay had been pressed into the base of the cut, and lumps of clay were present through the feature's fill. Ochre pieces were recovered from fill [21] within the pit (n = 4), and adjacent to the pit in spits 3 (n = 13), 4 (n = 6) and 5 (n = 7). Ochre was only present in excavation squares 3 and 4 and had a direct association with the pit (Figure 4). The ochre was a ferruginous sandstone derivative, with observable nodules of iron in some of the larger ochre pieces. A total of 30 pieces of ochre, 22 red and eight yellow, were recovered (Table 1, Figure 5A).

The presence of ochre surrounding the pit, and within the pit's fill, and the similarity of this feature to other reported cultural cooking pits in Parramatta (e.g., site AT14, GML, 2021) led to the interpretation that the feature was an ochre heating pit. The clay pressed into the cut of the pit was likely used to assist in baking the ochre – which was possibly undertaken to control or modulate the temperature. Elsewhere ochre was sometimes baked, for cultural reasons, to change its properties, and/or colour, from yellow to red (O Foghlu, 2021, p. 206, 286).

We interpret the ochre feature as being associated with the PSB of spit 3 (Figure 2). Ochre recovered adjacent to the feature from spits 4 and 5 is probably a result of localised site formation factors, most likely human agents (e.g., excavation, raking out, maintenance, etc.).

In addition to the ochre, eight stone artefacts of quartz, silcrete and indurated mudstone silicified tuff chert (IMSTC) were recovered. The deepest silcrete lithic was recovered from square 4, spit 5 (Table 1), beneath the lower

Figure 3. Trench western section and base, annotated with the depth of each hand excavated spit, showing the position and depth of the upper three OSL samples. Prior to the removal of spit 7.

pit cut. There was limited evidence for bioturbation in the trench sections (sporadic cicada burrows and some small tree roots), and we acknowledge that the small size (5 mm by 4 mm by 6 mm) of the lowest artefact *could* have made it susceptible to downwards movement through the PSB. The other lithics present were in spits 1 and 2, above the pit feature. None of the artefacts refitted – there were no conjoins.

At the other end of the temporal scale a single ceramic flake with pressure damage around all margins was found in spit 1 (Figure 6). The ceramic was a fine white glazed sherd, with a partial scar on the dorsal surface, indicating the removal of at least one other flake from the ceramic 'core' prior to the removal of this flake. It was classified as either "whiteware", introduced in the 1820s, or porcelain – the date for a porcelain object in this context could be from 1788. The item provides evidence for 'contact period' presence of Aboriginal (Burramattagal) people in and around Government House.

Particle-size analysis

Wind-reworked fluvial deposits are identified as a significant archaeological environment in the Sydney Basin, containing "the oldest archaeological sites in the Sydney district" (Gale & Wales, 2023, p. 1). Confirmation that aeolian processes have formed a deposit can be "formidable"; however recent publications have clearly demonstrated an aeolian mechanism for formation at both Agnes Banks, western Sydney (Gale & Wales, 2023, pp. 18–19), and from PSB in Parramatta (Quinn et al., 2023, p. 6). In both locations there is clear particle size evidence to demonstrate downwind fining creating source-bordering aeolian dunes.

Despite its certain sedimentological origin, the various lithological expressions across the PSB can largely be attributed to pedological processes overprinting the original sediment deposit. At site CG1, where the archaeological importance of the PSB was first demonstrated, the visual down-profile appearance of the archaeological context was almost uniform, apart from the occurrence of post-depositional iron oxide segregations at depth (JMcD CHM, 2005b). Direct stratigraphic interpretations are therefore difficult to infer from visual observations, so we undertook a detailed down-profile particle-size analysis.

A location along the archaeological section, at approximately the mid-point of excavation square 2 (Figures 2 and 3), was selected for sampling. The location was immediately adjacent to the ochre heating or processing pit, but also the least affected by visually evident bioturbation. Two replicate sets of samples, A (n = 24) and B (n = 24), at an approximately 10 cm horizontal separation were extracted from the section at 5 cm depth-increments from 0.05 m to 1.2 m below the ground surface. Each sample was retrieved using an approximately 2 cm diameter steel tube and transferred to a small, labelled plastic bag.

Table 1. Overview of contexts, spits and correlation between depositional and archaeological results.

Spit	Context	Spit depth (mm)	RL (AHD) at top of spit or feature	OSL sample depth (m) in section	Age (k BP) at top of spit	Lithics	Other cultural evidence
Fill	03	250	9.64 m	—		0	0
1	15	180	9.39 m		~0.6 (inferred)	1 silcrete angular fragment 1 silcrete medial flake 2 IMST flakes	1 ceramic scraper
2	16	100	9.21 m	0.18	19.1 ± 1.6 [top] OSL 010	2 quartz angular fragments 1 quartz flake	0
3	20	100	9.11 m	0.28	32.6 ± 2.4 [top] OSL 011	0	10 red ochre 3 yellow ochre (1 with use-wear)
Pit cut & fill	21	140	9.06 m	—	Between OSL 011 and 012	0	4 yellow ochre
4	23	100	9.005 m	0.39	37.6 ± 2.6 [top] OSL 012	0	6 red ochre
5	24	120	8.91 m		+40 (inferred)	1 silcrete angular fragment	6 red ochre 1 yellow ochre (with use-wear)
6	25	40	8.81 m		—	0	0
7	26	570	8.77 m	0.68 1.08	49.0 ± 3.2 OSL 013 43.8 ± 2.6 OSL 014	0	0
8	—	—	8.20 m	—	—	—	—
Totals						8	31

Preparation of the samples for analysis was conducted following methods modified from Gale and Hoare (1991) as follows. Each sample was air-dried, carefully ground and homogenised with a mortar and pestle and ensuring that individual grains were not fractured. Each sample was then passed through a 2 mm sieve, although no individual mineral grains were found to be greater than 2 mm.

A small spoon was used to transfer approximately 0.5 g of the homogenised sample into a labelled 100 mL beaker. Organic materials were removed by immersing a sample in ~30% v:v hydrogen peroxide for approximately 2 hours and then heating to above 70°C until reaction had subsided. The sample was then transferred to a 50 mL centrifuge tube by washing with 0.5% sodium hexametaphosphate solution and filling to approximately 30 mL. The centrifuge tubes were agitated end-over-end for at least 16 hours before measurement in a Malvern Mastersizer 2000 laser diffractometer, at the University of Sydney. Simple graphical statistics were then calculated using the methods of Folk and Ward (1957).

Figure 7 is a biplot showing graphical mean particle-size plotted against depth (mASL) for replicate profiles A and B. The trends of the two lines agree well, suggesting the influence of bioturbation is minimal. Upwards from the base of the profile there is a slight but fining trend from 1.2 to 0.6 m. Between 0.6 and 0.45 m the trend changes to a slight coarsening trend, until a sharp shift to a coarser mean-particle size occurs above 0.4 m.

We interpret the abrupt upwards-coarsening of mean particle-size above the spit 6/7 boundary as a result of a change in sedimentary process from alluvial to aeolian. Once aeolian sedimentation became dominant, the finer fraction of materials sourced from the adjacent stream channel and bank was winnowed away, leaving deposition of the coarser and saltated fraction. This is in line with other sedimentary analyses of PSB from locations above c.7 m AHD (Gale, 2021, p. 7, 2022, p. 2; GML 2021; Player, 2019, p. 7; Quinn et al., 2023; Williams et al., 2012, p. 8; Williams et al., 2014; p. 737, Williams et al., 2021, pp. 7–8), and align with the definition of sedimentary signatures for aeolian reworking evidenced at Agnes Banks (Gale & Wales, 2023, pp. 18–19).

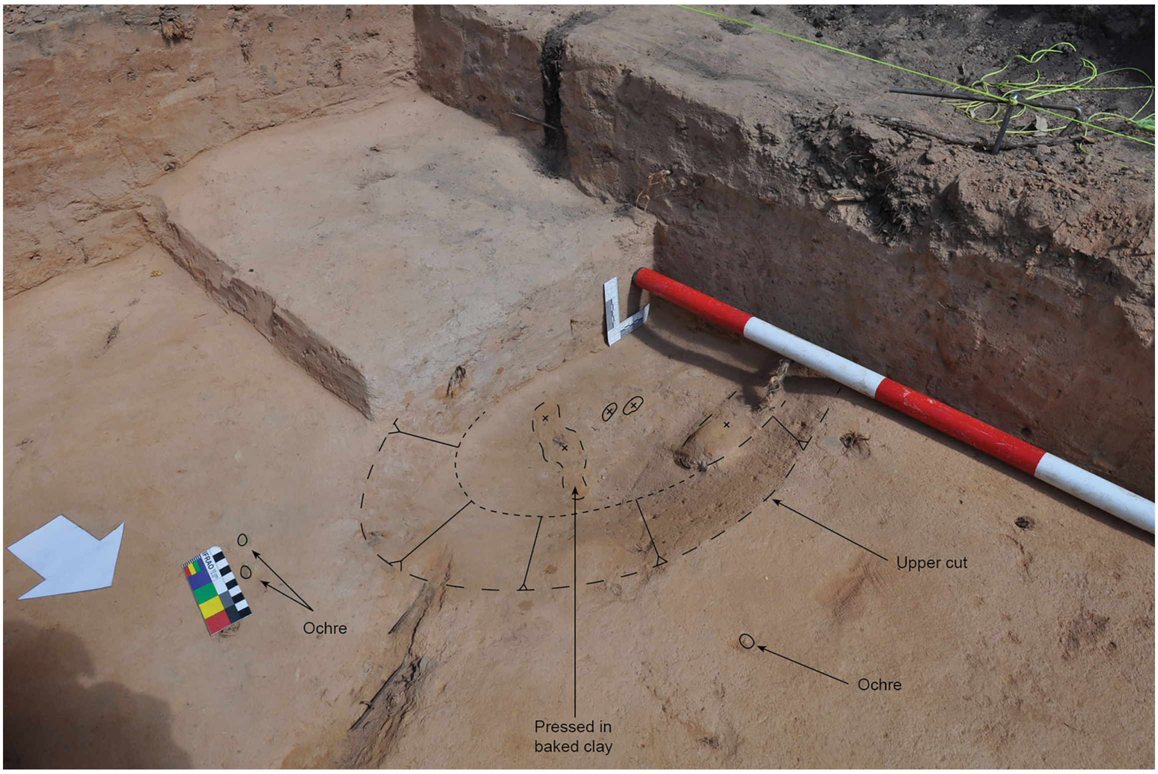
Optically stimulated luminescence (OSL) dating

Five samples were collected immediately adjacent to the particle-size samples, and deliberately placed on the upper boundaries of spits 2, 3 and 4 allowing each layer to be dated (Figure 2 and Table 1). The samples were delivered for multigrain OSL analysis at the University of Gloucestershire, UK (Toms, 2017). The methods of OSL sample preparation and analysis (Toms, 2017) are the same as those employed by the University of Gloucestershire for the majority of Parramatta's OSL samples (e.g., Barry et al., 2021) and Pitt Town (e.g., Williams et al., 2012, 2014).

The OSL ages (± 1σ) are reported in Table 2 and summarised thus:

- OSL 10, Age 19.1 ± 1.6 ka
- OSL 11, Age 32.6 ± 2.4 ka
- OSL 12, Age 37.6 ± 2.6 ka

Figure 4. Square 4, at the spit 3/4 interface, following excavation of the ochre processing pit. The cut of the pit presented an oval form, measuring 0.8 m by 0.4 m and 140 mm deep. Remnant patches of baked clay line the base of the feature. Yellow ochre pieces are located adjacent to the IFRAO scale and around the pit.



- OSL 13, Age 49.0 ± 3.2 ka
- OSL 14, Age 43.8 ± 2.6 ka

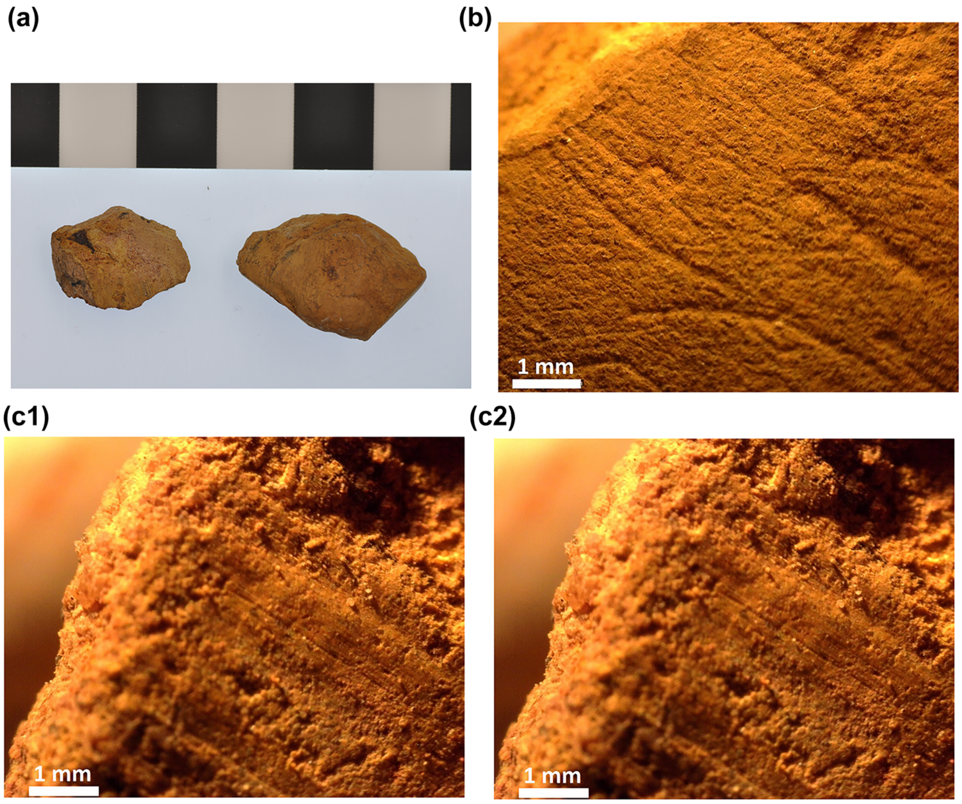
The Dose Rate (D_r) values are based on *ex situ* Ge gamma spectrometry, dose rate conversion factors (Adamiec & Aitken 1998), grain size (Mejdahl, 1979), burial moisture content (Zimmerman, 1971; assumed synonymous with present moisture content), depth, site surface altitude and a geomagnetic latitude of 38°S (Prescott & Hutton, 1994). No significant U disequilibrium was detected. Equivalent Dose (D_e) values are based on conventional multi-grain, single-aliquot regenerative-dose (SAR) OSL measurements of fine sand quartz (Murray & Wintle 2000, 2003). As multi-grain, single-aliquot measurements of Australian quartz with its relatively large proportion of OSL-bearing grains, overdispersion of D_e values (Galbraith et al., 1999) are predictably small. However, the magnitude of the D_e values suggests the influence of external drivers on inter-grain D_e variation would be limited and reduce with increasing depth/age (Galbraith et al., 2005; Olley et al., 2004). Age estimates are based on the Central Age Model (Galbraith et al., 1999) and expressed relative to year of sampling (2016). Refer to Supplementary Material - OSL graphs for specific details.

The upper three reported OSL ages (OSL 10, 11 and 12) exhibit a sequential accumulation of sediment, the lower-two age determinations (OSL 13 and 14) are statistically indistinguishable at 95% confidence. Each of the lower-two samples underestimated the applied laboratory dose of ionising radiation. Using the applied laboratory dose as an estimate for a natural burial dose may therefore underestimate their age, but this would likely be within the reported uncertainty range. We note the resulting ages of OSL13 and OSL14 are of the same order as the thermoluminescence ages reported by Mitchell (2010) for the site at 140 Macquarie Street, Parramatta (and also comparable to other, as yet published, samples from both Robin Thomas Reserve and Phillip Street).

As the ochre pit feature was cut from intra-spit 3 into spit 4 sediments, it is younger than spit 4, and represents occupation buried by spit 3 sediments. As such the feature was probably made some time between the age determinations obtained for OSL11 and OSL12. This would give an age somewhere between ~40.2 ka and 30.2 ka, and more likely within the younger half of that age range, between ~35 ka and 30.2 ka (being OSL11).

The artefacts in spit 2 would have accumulated sometime between OSL10 and OSL11. This would give an age somewhere between ~35 ka and 17.5 ka. The artefacts in spit 1 could be younger than OSL10, making them less than ~20.7 ka to 17.5 ka. It is presumed that the ceramic flake in spit 1 was displaced downwards by modern land use, from the overlying mixed historical topsoil.

Figure 5. (a) Two yellow ochre pieces with evidence for use-wear; scale bar = 1 cm. (b and c) microscopic photography of the use-wear on the two pieces.



Microscopic use-wear analysis of the ochre

All 30 ochre pieces and the ceramic flake were subjected to microscopic use-wear analysis, which was undertaken according to established, conventional methods (for comprehensive descriptions see Munt, 2022, pp. 162−167). Evidence for use was examined first macroscopically, and then at low-magnification (up to x100), followed by high magnification (up to x500) under an *Olympus* BH-2® metallographic microscope, with vertical incident lighting, brightfield/darkfield and long working distance objective lenses (total magnifications ×50, ×100, ×200 and ×500). Analysis investigated for the presence and nature of all forms of use-wear: (i) polish and abrasive smoothing; (ii) striations; (iii) edge scarring; and (iv) edge rounding. Evidence for manufacture (as distinct from use-wear) of the ceramic item was also investigated.

Two of the ochre artefacts display use-wear. Ochre artefact 1 from square 3 spit 3, measures 24 × 16 × 10 mm, and weighs 3 g (so potentially of a useable size). It displays prominent grooves, which extend from the edges and have unfrayed terminations (Figure 5A (left), 5B). The grooves are predominantly parallel to each other, and micro-striations are present within some of the grooves. The edge of the artefact became rounded to a considerable extent. These characteristics are distinctive of grinding, rather than other tool motions, such as scoring or rubbing (Hodgskiss, 2010, pp. 3347−3352, 3354−3355, 3357; Velliky et al., 2018, p. 18).

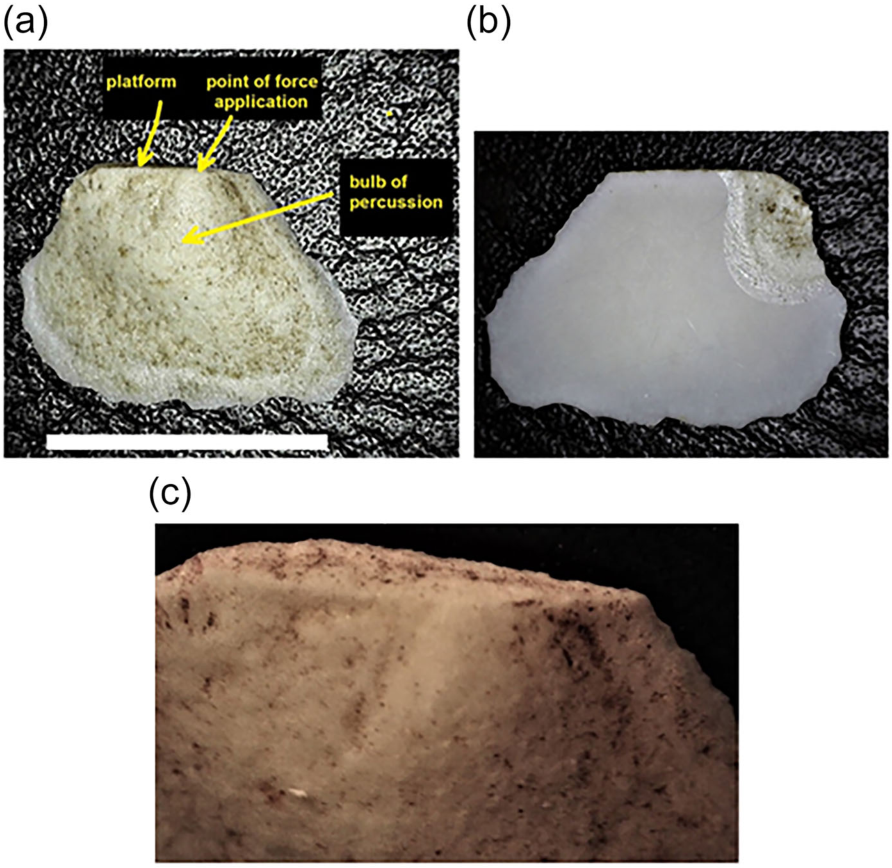
Ochre artefact 2, from square 4 spit 5, measures 17 × 14 × 7 mm, and weighs 1 g (Figure 5A (right), 5C). It is extremely similar to artefact 1. There is a particularly clear distinction between the smoothed, ground region and the unground parts of the surface. Grooves are also parallel but, in contrast to ochre artefact 1, emanate a slight distance from the edge – which can occur after scoring rather than grinding (Hodgskiss, 2010). However, the incisions do not have a variety of profile shapes, which is sometimes the case after scoring, and all other aspects of these grooves and the surface are consistent with grinding.

The ceramic flake had no evidence for tool use, but clear indication of anthropogenic knapping. The distinct ventral surface had a pronounced bulb of percussion, platform and point of force application (Figure 6).

THE ANTIQUITY OF OCHRE USE BY ABORIGINAL AUSTRALIANS

Aboriginal Australians used ochre upon their first arrival in the continent around 65000 BP (Clarkson et al., 2017). The next oldest ochre are fragments from Warratyi Cave in central Australia, interpreted on the basis of residue analysis as used for pigment production, and dated to

Figure 6. Ceramic flake. (a) ventral surface; scale bar = 1 cm. (b) dorsal surface. (c) close-up of ventral proximal margin with the platform, point of force application and bulb of percussion.



≥49000−46000 BP (Hamm et al., 2016, p. 282, referring to their OSL and calibrated C14 dates). At Carpenter's Gap 1 in north-west Western Australia (WA) a rock slab was painted with ochre approximately 40000 years ago (O'Connor & Fankhauser, 2001). Across many subsequent millennia and over a variety of locations in the country, ochre was used for a range of symbolic activities, particularly manufacturing pigment for use in rock art (e.g., Attenbrow, 2010, p. 151; David et al., 2017, p. 297; Delannoy et al., 2017, p. 217; May, Shine, et al., 2017, pp. 61−62; McDonald, 2008, pp. 221−228). It was also used for body painting (Huntley, 2021, p. 5; May, Shine, et al., 2017, p. 62; May, Taçon, et al., 2017, p. 87), toys, weapons, ritual objects, ointments, parasite repellent and preservative for food and wooden implements (Huntley, 2021, p. 6 and references therein). Ochre was important in ritual activities, such as at Lake Mungo in far western NSW, where a body was covered with ochre during one of the world's oldest known ritual human burials around 40000 years ago (Bowler et al., 2003). It was also part of complex trade and exchange networks operating over vast distances of the continent (Huntley, 2021, pp. 4−6, 13; McBryde, 1987).

In marked contrast to this early evidence of ochre use, studies of the rock art in the Sydney Basin have, until now, found no firm evidence for ochre-use until around the mid-Holocene (Attenbrow, 2010, pp. 150−151; Clegg, 1987; Dibden, 2019, p. 123; McDonald, 1991, 2008, p. 44, 249; McMah, 1965; Tasire & Davidson, 2015, p. 49). Archaeological excavation at Randwick recovered ochre adjacent to a hearth, that was radiocarbon dated to 8800−8590 calBP (Wk-50387) from the Botany sands (GML, 2020); and from shallow undated sediments in Parramatta, but estimated to be middle Holocene based on the attributes of the associated lithics assemblage (Comber, 2020, pp. 30−31).

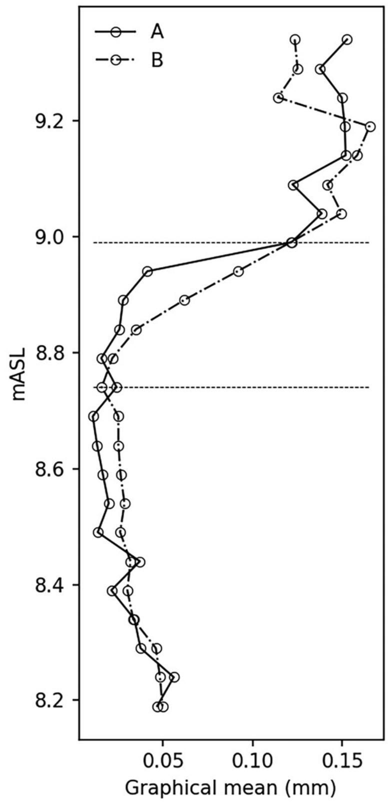
The presence of utilised ochre at the GSG site, at such an early time, is highly significant in this context, and places the Sydney Basin firmly with other Australian regions for pre-LGM use of ochre.

The use of the ochre almost certainly reflects symbolic expression, extending the known antiquity of symbolism in Parramatta and the Greater Sydney Basin by some 25000 or so years. Our evidence suggests that the ochre was ground into a powder. There is no contextual evidence to indicate the specific purpose for the powder, and various definitions exist for "art", but based on the widespread practice from other parts of the country, the powder may indeed have been used for a form of art.

Table 2. OSL results, Dose Rate (D_r), Equivalent Dose (D_e) and Age data of OSL samples processed from GSG, Parramatta. 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. Blue indicates samples with accepted age estimates; red indicates age estimates with analytical caveats (failed Dose Recovery test; Murray & Wintle, 2003).

Field code	Lab code	RL AHD (m)	Moisture content (%)	γ D_r (Gy/ka)	β D_r (Gy/ka)	Cosmic D_r (Gy/ka)	Total Dr (Gy.ka^{-1})	D_e (Gy)	Overdispersion (%)	OSL age (ka)
GML OSL 010	GL16169	9.21	0	0.74 ± 0.07	0.68 ± 0.07	0.14 ± 0.03	1.55 ± 0.08	29.7 ± 1.9	19	19.1 ± 1.6 (1.4)
GML OSL 011	GL16170	9.11	0	0.70 ± 0.07	0.61 ± 0.07	0.13 ± 0.02	1.45 ± 0.08	47.1 ± 2.4	13	32.6 ± 2.4 (2.0)
GML OSL 012	GL16171	9.005	1	0.78 ± 0.07	0.71 ± 0.08	0.13 ± 0.02	1.63 ± 0.08	61.2 ± 2.8	10	37.6 ± 2.6 (2.0)
GML OSL 013	GL16172	8.77	4	0.96 ± 0.09	0.98 ± 0.09	0.12 ± 0.01	2.07 ± 0.10	101.3 ± 4.4	8	49.0 ± 3.2 (2.4)
GML OSL 014	GL16173	8.37	2	0.95 ± 0.09	0.98 ± 0.09	0.12 ± 0.01	2.05 ± 0.10	90.0 ± 3.3	4	43.8 ± 2.6 (1.8)

Figure 7. Biplot of graphical mean particle-size (mm) vs depth (mASL) of replicate sample sets A and B.



WIDER IMPLICATIONS FOR REGIONAL OCCUPATION

Investigations into the Pleistocene archaeological signature of the wider Sydney region, which includes Parramatta, commenced 75 years ago with studies by McCarthy (1948). Continuing investigations have identified multiple streams of evidence for Aboriginal occupation during the Pleistocene, between ~40–35 ka and ~12 ka (Barry et al., 2021; GML, 2019, 2022; JMcD CHM, 2005a, 2005b, 2006; Nanson et al., 1987; Player, 2019; Quinn et al., 2023; Stockton & Nanson, 2004; Williams et al., 2012, 2014, 2021).

The Pleistocene is generally divided into epochs described by changes to sea level below the modern AHD, temperature and precipitation. The pre-glacial (~40 ka to ~30 ka), and early glacial (~ 30 ka to ~ 22 ka) gave way to the Last Glacial Maximum (LGM) (~22 ka to ~18 ka), during which sea level was up to 120 m lower (Albani et al., 2015, p. 683). At the height of the LGM (~20 ka), the Sydney coastline was approximately 25 km east of today's shoreline (Figure 1).

The earliest pre-glacial evidence for First Nations occupation in the Sydney region has been recovered from archaeological sites in just three regions: on the Nepean River associated with Cranebrook Terrace, the Hawkesbury River on the Pitt Town and Windsor sands, and adjacent to the Parramatta River at Parramatta. On the Hawkesbury

River, samples from elevated terraces comprising localised sand bodies at Pitt Town (PT-12) and Windsor (South Bank PAD W-SP #45-5-3581) have returned pre-LGM OSL age determinations of ~36 ka (Austral Archaeology, 2011; Williams et al., 2012, 2014). Further south-west the Cranbrook Terrace yielded stone artefacts with associated sediments thermoluminescence dated to ~40 ka (refer to discussions in Mulvaney & Kamminga, 1999; Nanson et al., 1987; Stockton & Nanson, 2004; Williams et al., 2017).

Prior to this study, Parramatta had presented two sites with pre-LGM evidence for First Nations occupation, both from the PSB. At RTA-G1, located around 1 km east of the GSG site, charcoal collected from the base of the excavation provided a date of 35060−34240 calBP (Wk-17435). Preliminary interpretation of the site and its formation suggested that artefacts from the lowest layers were "likely to be older than 28,000 years" (JMcDCHM, 2005a, pp. 108–125, 138) – noting the authors were commenting on the uncalibrated date.

Firm evidence for occupation prior to the LGM was obtained from site AT14, also on the PSB and located approximately 1.2 km north and upstream from GSG (GML, 2022; Quinn et al., 2023). This site included a pre-LGM deposit of lithics, manuport cultural stone and cultural features. Radiocarbon dates from two spatially separate cultural features were remarkably similar (35100−34250 calBP, Wk-52574; and 34850−34150 calBP, Wk-52567) and paired to OSL dating (31 ± 2 ka) for the pre-LGM archaeological layer (Quinn et al., 2023).

The age determinations and presence of cultural materials at the GSG site are consistent with the initial results from site RTA-G1 and the more substantial results from AT14.

A previous model for regional occupation before, through and after the LGM, identified the Sydney Basin bioregion as a possible refugium (Barry et al., 2021; Williams, 2013; Williams et al., 2021). The demographic model proposed by Williams (2013), furthered through consequent publications (Williams et al., 2021), suggested regional low density established occupation pre-LGM, a population 'nadir' following the LGM, and increased population at the end of the Pleistocene and early Holocene. The model evolved on the basis of dated archaeological evidence from archaeological sites on the Hawkesbury River and interpretation that archaeological evidence at Parramatta was not earlier than c.14 ka. Pre-LGM occupation is described as being restricted to cryptic refuges in the Hawkesbury-Nepean River corridor, with expansion away from this refuge only towards the end of the Pleistocene. The Blue Mountains are described as a physical barrier preventing pre-LGM and LGM movement into the region. It was proposed that any pre-LGM population movement could have been along the Pleistocene continental shelf prior to its inundation (Figure 1).

Expanding this model, Parramatta could be considered a further refugium, notable as a cultural landscape with multiple resources suitable for long-term human habitation (Owen et al., 2022). Parramatta's pre-LGM occupation resulted in the retention of a variety of archaeological materials (lithics, manuport stone, hearths and ochre), so far identified within three separate landforms. Some of Parramatta's elevated locations (AHD +7 m) have sedimentary parallels with the sand bodies along the Hawkesbury-Nepean Rivers, being source bordering dunes (Gale & Wales, 2023), and their periods of occupation are similar. To date, all identified pre-LGM Sydney archaeological sites present a focus connecting them to major waterways draining towards the coast, and aeolian sand bodies with deep stratified sequences. We note this correlation could be a factor of site formation and retention of archaeological evidence, rather than reflecting favoured occupation locations (cf. White, 2021). If occupation of this region commenced from ~35 ka or earlier, First Peoples entered into an environment substantially different from that of today, one that was drier and colder, probably with an open woodland environment. Taking into account the pollen studies (e.g., Chalson & Martin, 2008), and modern vegetation changes across the region (Tozer, 2003; Williams et al., 2006, p. 746), it is feasible that long-term subsistence strategies could have focused on resources associated with ecotones connected with the riverine systems.

Models for Pleistocene occupation of the Sydney Basin have examined social and demographic factors (McDonald, 2008, p. 349; Williams et al., 2021). However, the viability for human movement and/or habitation of the inundated pre-LGM landmass (Figure 1; Albani et al., 2015) is yet to be considered. Reconstruction of the bedrock geomorphology across the now inundated coastal Pleistocene landmass describes 15 major drowned river valleys between the Hawkesbury River and Georges River (Albani et al., 2015, fig. 3). Five of these drowned valleys (Pittwater, Hawkesbury, Parramatta, Botany and Georges Rivers) have relief +60 m creating deep gorges which would have been difficult to traverse, likely forcing movement inland or seaward. The nature of the landmasses in-between the river valleys is unknown. Some may have been inhospitable with further expressions of the aeolian dune systems, such as the Quaternary age Botany Sands (Gale et al., 2018, figs. 1 and 2), extending to the paleo-shoreline. Conversely, some landforms abutting rivers such as North Head, South Head, Peak, Maroubra Long Bay rivers, have very low relief creating gently undulating rises. These could have provided substantial flat plains with woodlands suitable for long-term habitation, allowing people to move upstream along valleys such as the Parramatta River.

CONCLUSION

The outcomes from this research have contributed significantly to our knowledge of ochre use, and evidence for when Aboriginal people commenced occupation on landforms adjacent to the Parramatta River. We hypothesise that aeolian redeposition of fluvial sediments from ~35 ka led to the burial, and hence survival, of evidence for pre-LGM occupation of the Parramatta area. We caution that a site-specific approach is required to understand localised PSB formation and the incorporation of archaeological evidence within this deposit. The regional importance of this work adds to an understanding that the PSB retains a pre-LGM to Late Holocene archaeological signature, comparable to that from other sand bodies within the Hawkesbury-Nepean River corridor. This furthers the datasets available for the development of regional occupational models and provides new directions for the next stages of investigation into Sydney's earliest archaeology.

ACKNOWLEDGEMENTS

Parramatta is in the traditional Country of the *Burramattagal*. The authors acknowledge the Traditional Owners of Parramatta, their lands, their people, and their connection, both now, of the past and into the future. This paper has been prepared to acknowledge and provide further understanding of Aboriginal traditions and continued connection with Parramatta. We wish to thank the Deerubbin Local Aboriginal Land Council for its assistance and work throughout the project and ongoing support for Aboriginal heritage in Western Sydney. The staff of the Western Sydney Parkland Trust (WSPT) are thanked and acknowledged for their support and comments on the draft of this paper. All archaeological works were undertaken pursuant of dual approvals under Section 90 of the NSW *National Parks and Wildlife Act 1974* (NSW) (AHIP C0001695), and Section 63 of the *NSW Heritage Act 1977* (NSW) (2013/S60/108).

Angus Bowen is thanked for the preparation of Figures 1–4.

Open access publishing facilitated by Flinders University, as part of the Wiley - Flinders University agreement via the Council of Australian University Librarians.

CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interests to declare with respect to this paper.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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