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Archaeological surfaces in western NSW: Stratigraphic contexts and preliminary OSL dating of hearths

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Abstract

A two-phase process for developing a chronology of Aboriginal occupation in arid western NSW, Australia, has been developed over the past ten years by the Western NSW Archaeology Program. Radiocarbon dating of charcoal from the remains of heat-retainer hearths, built by Aboriginal people in the past to cook food, and Optically Stimulated Luminescence (OSL) dating of sediments have been used to construct a chronology of 'archaeological surfaces'. Here we provide preliminary age estimates using OSL dating of stones from heat-retainer hearths which have previously been dated by radiocarbon. Our method is novel in several ways including the rapid preparation method adopted and the approach to estimating the dose rate for surface samples. We discuss the limitations of this virtually non-destructive and efficient OSL dating method, and provide an agenda for future technical development and application.

Keywords : Archaeological surfaces, OSL dating, heat-retainer hearths, Western NSW

Introduction

Surface archaeological deposits are widespread in western NSW (Figure 1), but have received relatively little attention, owing in part to the difficulty of providing chronological constraint. Heat-retainer hearths, or earth ovens, are most often found in association with stone artefact deposits, and radiocarbon dating of charcoal from the hearths is beginning to provide a powerful means of developing a chronology of occupation of the locations in which they are found (e.g. Holdaway et al. 2002, 2005).

Optically-stimulated luminescence (OSL) dating of sediments (Huntley et al. 1985; Rhodes 1988) provides an additional method which may be applied in these contexts. For example, Fanning and Holdaway (2001) used OSL sediment dating combined with ^{14}C dating of hearth charcoal to provide a chronology for archaeological material at Stud Creek in Sturt National Park in far northwest NSW (Figure 1). In later work, Fanning et al. (2008) found that the OSL signals of sediments from Fowlers Gap, NSW, were poorly bleached, but that single grain OSL measurements, combined with the minimum age model of Galbraith et al. (1999), provided reliable age estimates for deposition.

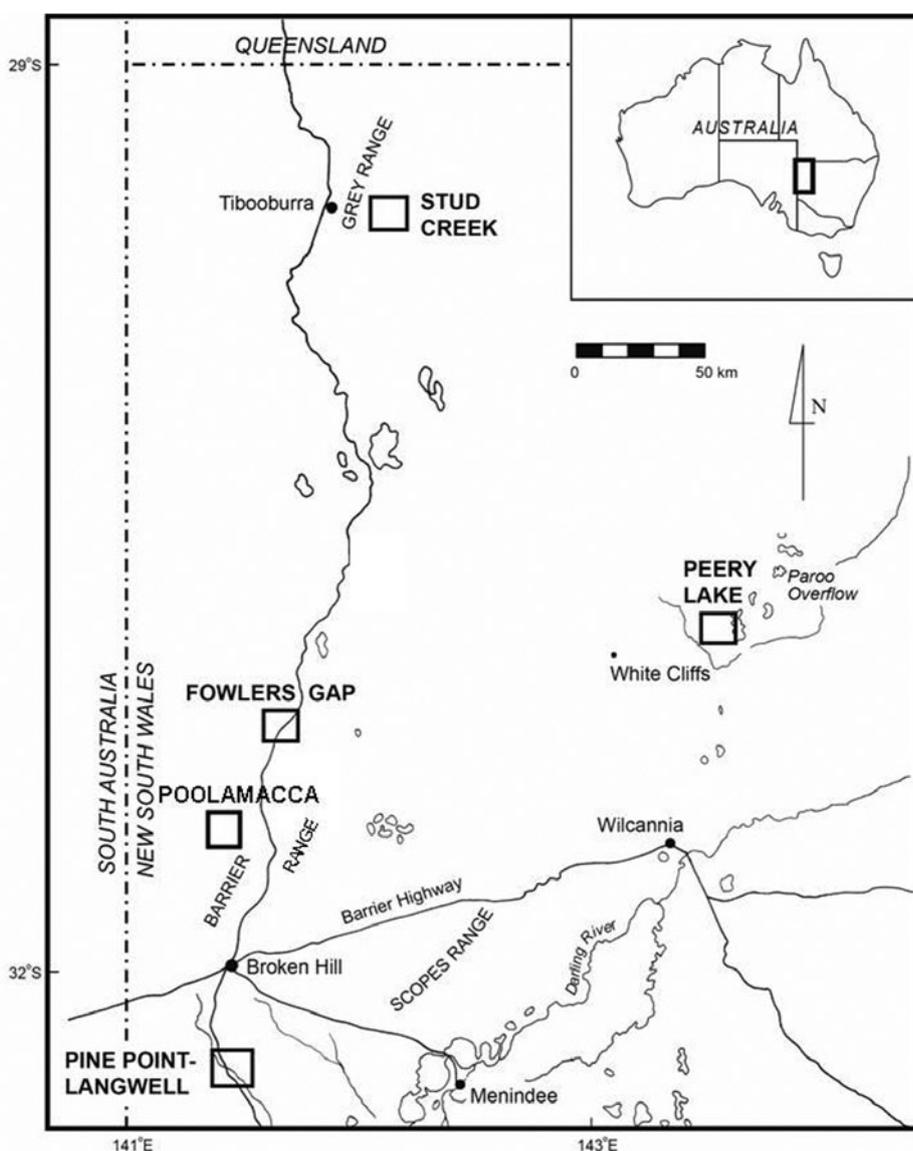


Figure 1. Map of western NSW, Australia, showing the locations of Fowlers Gap Arid Zone Research Station and the pastoral property known as 'Poolamacca'. Other Western NSW Archaeology Program (WNSWAP) research locations are also shown.

In this paper, we present preliminary OSL dating results for heat-retainer hearth stones, providing age estimates of the last heating event. These results are compared with radiocarbon determinations on charcoal from the same hearths, and provide powerful evidence of the potential of OSL for directly dating the hearths. One clear advantage of using OSL dating, in comparison with radiocarbon, is that it is far less destructive: only a small number of stones, between 1 and 4, need to be removed from the hearth for OSL dating, and no excavation is required. In contrast, for reliable radiocarbon dating, a significant proportion (typically one quarter to one half) of a hearth must be fully excavated to retrieve charcoal (see Fanning et al. this volume). Given the conservation concerns of heritage managers and the desire of Aboriginal people for their heritage to be left in place, a reliable alternative method of dating Aboriginal occupation is highly desirable. Moreover, this method, if successful, will allow age determinations of hearths where the charcoal is no longer present, thereby extending the data set from which an occupation chronology is constructed. The methods which we have developed for rapid preparation of the samples and the approach to estimating the past dose rate experienced by grains within hearth stones are both new. With further developmental work and more complete assessment, we consider that this OSL-based approach will provide a new means for archaeologists working in arid environments to determine a chronology of human activity without the requirement to excavate.

Nature of 'archaeological surfaces' in western NSW

The term 'archaeological surfaces' is used here to mean any land surface that contains deposits of stone artefacts and associated heat-retainer hearths. The processes involved in their formation have the potential to vary considerably, depending on the geomorphic setting and human occupation history, but detailed geomorphological and stratigraphic research of numerous surface archaeological contexts in western NSW reveals a similar story (Fanning 1999, 2000; Fanning and Holdaway 2001), as described briefly below.

Typically, a new land surface is constructed from the deposition of alluvial (water-lain) and/or colluvial (slope) sediments within part of a catchment, usually the valley floors, following, for example, a flood event. The 'surface' simply represents the last sedimentary unit deposited at each location. The surface is initially free of archaeology, although the sediments have the potential to contain reworked archaeological material from upstream locations. In western NSW, valley-bottom sediments comprise poorly-sorted silts (including pelletal silts) and sands (Fanning 1999; Fanning and Holdaway 2001), with occasional gravelly units. While archaeological material of coarser grade may be redeposited within the gravel units, it is rarely redeposited within sand or silt-dominated contexts.

In the following years, soil formation processes (weathering, bioturbation) will slowly modify the surface, and localised deposition of aeolian material may take place. At the same time, the surface is 'available' for human habitation, with the record of human activities taking place there being preserved in the archaeological material deposited upon it. This includes the construction of heat-retainer hearths, though it is important to note that these structures are constructed by digging down through the surface sedimentary unit, sometimes into underlying strata. Thus, the main part of the hearth may occupy space at a deeper (older) stratigraphic level (Figure 2).

The surface will continue to be available to 'collect' archaeological material until either buried by renewed deposition or eroded away. This may occur in localised patches, for example by limited aeolian erosion and deposition or limited surface fluvial activity, or it may occur over a greater area, for example by floodplain stripping or by widespread deposition of flood deposits caused by another flood event. In such cases, the upper surface of the new sedimentary unit becomes another archaeological surface, in turn retaining archaeological material deposited on it. Under this accumulation-dominated scenario, it is possible that a catchment may contain multiple archaeological surfaces of different ages, possibly stacked up one upon another.

In western NSW, however, the stratigraphic records of upland catchments are dominated by erosion (Fanning and Holdaway 2001; Holdaway et al. 2004). Accelerated erosion caused by overgrazing by cattle and sheep over the past 150 years is the principal determinant of the current high visibility of archaeological material at the surface (Fanning 1999, 2002). Once uncovered, however, these surface archaeological deposits have a very limited lifespan. Much of the archaeological material currently exposed in these contexts is in highly unstable locations, and is unlikely to survive more than two or three decades (Fanning et al. this volume).

Figure 2 represents the typical sedimentary and archaeological relationships that exist in much of western NSW today. The original archaeological surface is represented by the boundary between layers B and C. Archaeological material (lithic artefacts and debitage, bone and other materials) is found at this level as indicated by the symbol. Note that some movement of material within the sediment by bioturbation and other processes such as swelling and contraction during wetting and drying cycles, and very localised erosion and redeposition, means that archaeological material can extend over a depth range of several cm, rather than lying on exactly one surface.

Typical hearth-sediment relationships are also shown in this figure. Hearths are constructed down from the archaeological surface (layer B–C interface) into layer B. Field observation suggests that hearths extend to a range of depths, but rarely penetrate the more consolidated, fine-grained underlying sediments represented by layer A in Figure 2.

Building a geo-archaeological chronology

The Western NSW Archaeology Program (WNSWAP) has, over the past ten years, developed a two-phase dating framework for developing a chronology of both landform development and human occupation at our field sites. The first phase consists of stratigraphic analysis and dating of the valley fill sequences described above, primarily using Optically Stimulated Luminescence (OSL) to date the sedimentary units above and below the ‘archaeological surfaces’. This is described in detail in Fanning et al. (2008). The second phase consists of age determinations on the heat-retainer hearths excavated by Aboriginal people into the ‘archaeological surfaces’ in the past. Up to now, we have relied on partial excavation of these hearth remains to extract a sample of charcoal

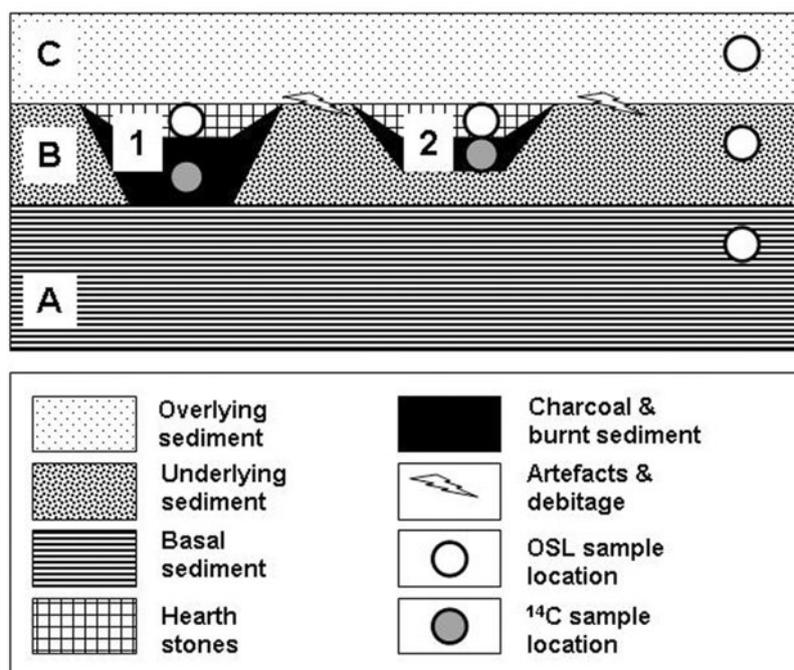


Figure 2. Typical sedimentary and archaeological relationships that exist in much of western NSW today. Three sedimentary units are indicated with different hatching and by the letters A, B and C. The archaeological surface is represented by the boundary between layers B and C, and was available to retain archaeological material after the deposition of unit B, but before the deposition of unit C. Archaeological materials (lithic artefacts and debitage, bone and other materials) are found at this level as indicated by the symbol. Hearths are constructed down from the archaeological surface (B–C interface) into layer B. Field observation suggests that hearths extend to a range of depths, but rarely penetrate the more consolidated, fine-grained underlying sediments represented by layer A. Also shown is our simplified dating strategy, dating the charcoal of the hearths using radiocarbon, and dating the heating of the hearth stones and the deposition of the underlying and overlying sediment units using OSL.

for radiocarbon dating. Here, we describe a new alternative method, using OSL techniques, which may in the future eliminate the need for excavation. We explore the potential of this approach by comparing OSL and ^{14}C age estimates from the same hearths from two separate locations in western NSW (Fowlers Gap Arid Zone Research Station and the pastoral property known as 'Poolamacca' — Figure 1).

1. Dating heat-retainer hearths using ^{14}C

The approach to dating heat-retainer hearths using ^{14}C is described by Holdaway et al. (2002, 2005). Not all hearth remains contain charcoal; only one third of all hearths excavated in western NSW over the past ten years contained identifiable charcoal suitable for dating. This limits the detail with which a chronology can be constructed, and demands excavation of a large number of hearths. The excavation process can be relatively slow, and the charcoal requires significant laboratory processing to isolate an uncontaminated sample. Excavation is at least in part destructive, and is understandably discouraged by heritage managers and Aboriginal people. Hearths with significant quantities of charcoal can be dated using conventional methods, but more expensive AMS dating is required for small samples (i.e. less than a few grams).

The chronological data provided by ^{14}C dating are of high accuracy and reliability, though plateau effects and the anthropogenic release of dead carbon reduce resolution at certain periods, especially for material from the last 250 years. It is possible that the preservation of charcoal is significantly better for younger hearths, biasing the chronological dataset towards younger age estimates. However, preservation is controlled by the degree of erosion at individual hearth locations (Fanning et al. this volume), which has been demonstrated to be independent of age within the context of a single archaeological surface (Holdaway et al. 2002).

2. OSL dating of hearth stones — a potential non-destructive alternative

OSL signals are reset by heating as well as by light exposure (Smith et al. 1986). This provides the possibility of using OSL to date the last heating of hearth stones. For a five minute heat treatment, virtually all the OSL signal of quartz is removed at a temperature of 300°C (Smith et al. 1986; 1990). For longer heating durations, lower temperatures have a similar zeroing effect. These temperatures are well within the range of those experienced within typical wood-burning fires, and penetration of temperatures in excess of several hundred degrees Celsius to the interiors of cobble-sized and smaller hearth stones is considered likely. If insufficient heating were experienced, age over-estimation would result.

This method has the potential to be significantly less invasive than ^{14}C , as stones currently exposed at the ground surface within the hearth structure can be collected for dating, and no excavation is required. Possible limitations of the technique are encapsulated in the following questions:

1. Was the OSL signal zeroed?
2. Are the OSL signals of light-coloured and translucent rocks bleached (i.e. reduced) by light exposure at the surface following erosive exposure of the hearth before sample collection?
3. Is it possible to deal adequately with the complex geometries of hearth and surrounding sediment and missing overburden when estimating the environmental dose rate?

2.1 Sample selection and collection procedure

For this pilot project, primarily designed to assess the feasibility of using OSL for dating heat-retainer hearth structures, we deliberately selected stones from a range of available lithologies, including some highly translucent rock types such as vein quartz. For some hearths, only one stone was selected, while for others up to four stones were collected. It is important that we have a high degree of confidence that the selected stones were part of the identified hearth structure. For this reason, stones showing obvious signs of burning, including colour change, fire-cracking or conjoining, and pot-lid or other thermal fracturing structures were favoured, and stones from outside the hearth cluster were generally avoided. For this assessment project, both large (cobbles of up to 15 cm diameter) and small stones (pebbles down to 2 cm diameter) were selected.

Using a portable gamma spectrometer with a 3" NaI crystal, a 900 s (15 minute) measurement was made at the surface of the hearth. This provides an environmental gamma radiation determination with a 2π geometry. Gamma rays enter the crystal from the underlying sediment and hearth, travelling approximately 30 to 40 cm from a half sphere beneath the crystal. No contribution can be measured from sediment that previously covered the hearth, as this has already been eroded and redistributed elsewhere in the landscape. Thus, for the age estimates presented below, this 2π geometry measurement has simply been doubled to provide a proxy 4π geometry estimate. Note that this procedure implicitly assumes that the samples were previously buried by at least 30 cm of overburden with a similar composition to the surface material on which the hearth lies. We consider this one of the main significant unknown factors in this approach, and the comparison with radiocarbon dating is intended to assess the validity of the methods which we have adopted. No correction for airborne radionuclide contributions has been made, though it is possible that ^{222}Rn and daughters, from the ^{238}U decay series, provide a small contribution to the measured ^{214}Bi and total gamma dose rate measurements.

2.2 Sample preparation

Our aim in preparing samples for OSL measurement is to achieve a quartz-dominated separate, and to employ a single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle 2000). The degree of quartz purity required for reliable OSL age determination depends on the luminescence characteristics of the quartz and other minerals present within the available lithologies. Some rocks selected are pure quartz (e.g. vein quartz), others are quartz-dominated (e.g. quartzite), while others contain significant quantities of other minerals (e.g. metamorphic rocks, sandstone). Quartz OSL signals have been demonstrated to undergo the 'predose effect' (Aitken 1985; Smith et al. 1986; Smith and Rhodes 1994), which leads to a significant increase in luminescence sensitivity as a result of heating for many samples. As all of the samples selected have been heated in the past, we expected to encounter high sensitivity OSL signals.

With these considerations in mind, and with the desire to develop a procedure which could be applied to a large number of samples, but where accuracy is limited by environmental dose rate estimation, we have opted not to undertake a full 'quartz inclusion' preparation protocol (Fleming 1970). Instead, we simply isolated rock from at least 3 mm inside each stone, and ground this to sand-size particles under acetone using an agate mortar and pestle. After grinding, samples were treated with dilute HCl and subsequently dried. Resultant grains were mounted on stainless steel discs using silicone oil for OSL measurement.

2.3 OSL measurement

All measurements were made in a Risø TL-DA-15 mini-sys automated luminescence reader. OSL measurements were performed at 125°C, and were preceded by IRSL measurements at 60°C. Natural and regenerative-dose measurements were preceded by a preheat of 220°C for 10 s, while sensitivity measurements were preceded by a heat of 200°C for 10 s, as used by Rhodes et al. (2003). Three discs of each sample were measured, using a post-IR OSL protocol, similar to that described by Banerjee et al. (2001).

For many samples, intense, rapidly decaying natural and regenerated OSL signals were observed, typical of quartz. Samples showing bright OSL signals displayed a linear dose response, and good agreement between the three measured aliquots was observed. Several samples had only very low OSL signal sensitivity (Tables 1 and 2), and some samples displayed significant IRSL signals. This latter observation may suggest that a more rigorous preparation including HF treatment may be advantageous for those lithologies.

2.4 Age calculation

Age estimates were calculated using the weighted mean of the three measured equivalent dose (De) determinations for each sample. For the dose rate calculation, the signal was assumed to come dominantly from sand-sized grains with negligible internal dose rate, and insignificant external alpha particle contributions. These assumptions may be worthy of further investigation in the future. The beta

dose rate for each rock was calculated using ICPMS measurement of U, Th and K content, and the gamma dose rate used was simply twice the measured 2π geometry measurement at the surface of each hearth. An overburden thickness of 50 cm was assumed for every rock, in order to calculate the cosmic dose rate contribution using the formulae of Prescott and Hutton (1994). This assumption is difficult to support in every case: for most samples there is no information available regarding previous burial depth. However, for higher dose rate samples, the cosmic ray contribution represents a rather small component, and uncertainty in this parameter does not lead to a significant uncertainty in the age estimate. Where the burial depth was less than around 30 cm, the doubling of the measured surface gamma dose rate would not be valid, and the assumption of >30 cm burial may require further examination in the future. It is possible that the measurement of both low and high internal dose rate rocks from the same hearth might be used to overcome uncertainty in burial depth, by taking an isochron approach to subtract the more poorly known external (gamma and cosmic) dose rate.

Preliminary OSL dating results

The results shown in Tables 1 and 2 represent all those so far measured, and include samples from hearths without radiocarbon age control. These results are useful in assessing the technique, as they provide information regarding sample purity, OSL signal brightness and D_e consistency, and for hearths with more than one OSL age estimate, the degree of external consistency can be assessed. Note that OSL dating results are presented as years before AD 1950, so that they are directly comparable with calibrated ^{14}C age estimates. Where ^{14}C calibration leads to multiple peaks, the full range from maximum to minimum 2 sigma range is quoted.

Some of the OSL results listed in Tables 1 and 2 agree well with the corresponding calibrated ^{14}C age estimates (e.g. K0118, K0141, K0519, K0524), while others do not agree (e.g. K0115, K0120, K0526, K0547). Some OSL- ^{14}C sample pairs do not have overlapping 2 sigma age ranges, but do not disagree substantially beyond these (e.g. K0131, K0143, K0146, K0523, K0535, K0548).

At Fowlers Gap (Table 1), 19 OSL samples have corresponding ^{14}C age estimates. Of these 37% disagree strongly, 16% disagree mildly, while for 47% OSL and ^{14}C have overlapping 2 sigma uncertainty ranges. This sample suite contains a relatively high proportion of quartz and quartzite samples, and both over- and under-estimates in OSL age are observed. At Poolamacca (Table 2), 34 OSL samples have corresponding ^{14}C age estimates. Of these 24% disagree strongly, 9% disagree mildly, while for 67% OSL and ^{14}C have overlapping 2 sigma uncertainty ranges. This sample suite contains a lower proportion of quartz and quartzite samples, and under-estimates in OSL age are observed more frequently than over-estimates, of which there is just one (K0542).

In total, 53 OSL samples have corresponding ^{14}C age estimates. Of these 28% disagree strongly, 11% disagree mildly, while for 60% OSL and ^{14}C have overlapping 2 sigma uncertainty ranges.

Discussion

These preliminary OSL age estimates are very encouraging, as 67% of paired OSL and ^{14}C have overlapping 2 sigma uncertainty ranges at Poolamacca, and 60% for the two datasets combined. However, around one quarter of the OSL age estimates do not agree with their corresponding ^{14}C control, and it is clear that the method still requires a little refinement.

Within both datasets, several OSL age under-estimates are observed for quartz and quartzite samples. It is possible that these relate to the reduction of the OSL signal by daylight (bleaching) which penetrated the rock while it was exposed at the surface after erosion of the overburden and before collection. For other lithologies, this is considered very unlikely, owing to the presence of dark minerals, in particular iron oxides, which are strongly light-absorbent. It is clear, however, that signal bleaching has not adversely affected other quartz and quartzite samples, such as K0117 and K0118. Some rocks classified as quartzite are relatively dark, and therefore light-absorbent, though this is not usually the

Field code	Lab. code	Hearth code	Lithology	OSL initial intensity (c/s/mgGy)	Internal dose rate (mGy/a)	External dose rate (mGy/a)	Total dose rate (mGy/a)	1 sigma uncertainty (mGy/a)	Equivalent dose (Gy)	1 sigma uncertainty (Gy)	OSL age (years before AD1950)	1 sigma uncertainty (years)	Radio-carbon lab. code	Uncalibrated C-14 age (BP)	1 sigma uncertainty	Calibrated 2 sigma minimum (calBP)	Calibrated 2 sigma maximum (calBP)
FG03-03	K0113	SC69	quartz	20	0.01	1.38	1.39	0.04	9.30	0.72	6640	560	Wk-10279	588	59	490	650
FG03-04	K0114	SC69	quartz	20	0.24	1.38	1.62	0.04	2.58	0.84	1540	520	Wk-10279	588	59	490	650
FG03-05	K0115	SC69	quartzite	4240	0.90	1.38	2.27	0.08	0.81	0.02	300	15	Wk-10279	588	59	490	650
FG03-06	K0116	SC69	quartzite	520	0.84	1.38	2.22	0.08	0.00	0.04	-50	20	Wk-10279	588	59	490	650
FG03-07	K0117	SC13	quartz	20	0.01	1.30	1.31	0.04	1.35	0.19	980	150	Wk-10272	904	47	670	910
FG03-08	K0118	SC13	quartzite	3570	1.60	1.30	2.90	0.13	2.63	0.07	850	50	Wk-10272	904	47	670	910
FG03-10	K0120	SC24	quartz	100	0.20	1.30	1.50	0.05	1.18	0.17	730	120	Wk-10274	1349	69	1050	1330
FG03-11	K0121	SC24	quartzite	2870	1.46	1.30	2.76	0.12	4.45	0.09	1560	75	Wk-10274	1349	69	1050	1330
FG03-15	K0125	ND20	quartz	60	0.02	0.81	0.83	0.04	1.93	0.49	2260	600					
FG03-16	K0126	ND20	quartz	1540	0.01	0.81	0.83	0.04	0.17	0.02	140	20					
FG03-17	K0127	ND20	quartzite	8610	0.23	0.81	1.04	0.04	0.29	0.01	220	15					
FG03-20	K0130	MD158	sandstone	7780	0.24	0.70	0.94	0.04	0.98	0.02	990	55	Wk-10264	990	81	680	980
FG03-21	K0131	MD183	sandstone	31920	0.36	0.76	1.13	0.05	1.62	0.04	1380	65	Wk-10265	1144	45	920	1130
FG03-22	K0132	MD153	quartzite	190	0.19	0.74	0.94	0.04	1.38	0.03	1420	75	Wk-10261	960	47	730	930
FG03-23	K0133	MD153	sandstone	17370	0.12	0.74	0.87	0.04	0.97	0.03	1070	70	Wk-10261	960	47	730	930
FG03-24	K0134	NH1	quartzite	79650	0.19	0.94	1.13	0.04	0.34	0.01	240	15					
FG03-28	K0138	NH2	sandstone	8420	0.46	0.74	1.20	0.05	0.31	0.01	200	15					
FG03-31	K0141	NN05	quartz	970	0.16	1.30	1.45	0.04	0.69	0.08	420	55	Wk-10257	468	50	320	550
FG03-32	K0142	NN17	quartz	40	0.02	1.11	1.13	0.04	1.65	0.44	1410	390	Wk-10259	957	44	730	920
FG03-33	K0143	NN17	conglomerate	3360	0.22	1.11	1.32	0.04	1.45	0.03	1040	45	Wk-10259	957	44	730	920
FG03-34	K0144	NN20	quartz	40	0.04	1.22	1.26	0.04	0.66	0.11	460	85	Wk-10260	514	65	320	640
FG03-35	K0145	FC5	quartz	10	0.01	1.20	1.20	0.04	4.28	0.30	3500	280	Wk-9353	3392	49	3440	3700
FG03-36	K0146	FC22	quartz	40	0.00	1.26	1.27	0.04	3.46	1.60	2680	1270	Wk-9348	5243	164	5600	6300
FG03-38	K0148	FC460	quartz	540	0.03	1.25	1.28	0.04	0.46	0.05	300	40	Wk-10255	1963	55	1710	1990

Table 1. Preliminary OSL (bold) and ^{14}C age comparison from Fowlers Gap heat-retainer hearths, in years before AD 1950. Also shown are lithology, OSL test dose sensitivity; internal, external and total dose rates; equivalent dose values; radiocarbon codes, uncalibrated ^{14}C age, maximum and minimum calibrated ^{14}C age estimates. Note that multiple peaks in ^{14}C calibrations are not shown.

Field code	Lab. code	Hearth code	Lithology	OSL initial intensity (cis/1mg/Gy)	Internal dose rate (mGy/a)	External dose rate (mGy/a)	Total dose rate (mGy/a)	1 sigma uncertainty (mGy/a)	Equivalent dose (Gy)	1 sigma uncertainty (Gy)	OSL age (years before AD1950)	1 sigma uncertainty (years)	Radio-carbon lab. code	Uncalibrated C-14 age (BP)	1 sigma uncertainty	Calibrated minimum (calBP)	Calibrated 2 sigma maximum (calBP)
PL05-BS01	K0518	15004	meta-sst	13110	0.30	1.58	1.89	0.05	1.96	0.05	980	40	Wk-17577	5794	34	6430	6650
PL05-BS02	K0519	15011	meta-sst	4380	1.28	1.65	2.93	0.09	1.96	0.05	610	25	Wk-17569	647	48	530	660
PL05-BS03	K0520	15014	quartzite	6990	2.45	1.55	4.00	0.20	2.84	0.11	650	45	Wk-17570	1030	36	800	960
PL05-BS04	K0521	15014	quartzite	5	0.27	1.55	1.83	0.05	1.29	0.48	650	270	Wk-17570	1030	36	800	960
PL05-BS05	K0522	15027	quartzite	7460	0.34	1.57	1.91	0.05	1.18	0.05	560	30	Wk-17571	933	34	730	910
PL05-BS06	K0523	15028	quartzite	6460	0.82	1.48	2.30	0.07	0.76	0.03	270	15	Wk-17572	376	34	310	490
PL05-BS07	K0524	15028	meta-sst	6470	0.38	1.48	1.86	0.05	0.81	0.03	380	20	Wk-17572	376	34	310	490
PL05-BS08	K0525	15033	quartzite	17770	0.64	1.69	2.33	0.06	1.69	0.03	670	25	Wk-17573	912	36	680	910
PL05-BS09	K0526	15033	quartz	50	0.18	1.69	1.87	0.05	0.27	0.04	90	20	Wk-17573	912	36	680	910
PL05-BS10	K0527	15036	quartz	3360	0.32	1.56	1.87	0.05	0.19	0.01	50	5	Wk-17574	206	34	-11	310
PL05-BS11	K0528	15036	meta-sst	3050	1.57	1.56	3.13	0.13	0.62	0.02	140	10	Wk-17574	206	34	-11	310
PL05-BS12	K0529	15044	meta-sst	4760	0.66	1.56	2.22	0.06	0.71	0.05	270	25	Wk-17575	915	37	680	910
PL05-BS13	K0530	15045	meta-sst	72900	0.26	1.66	1.92	0.05	1.33	0.03	640	25					
PL05-BS14	K0531	15050	meta-sst	6780	1.68	1.82	3.50	0.14	5.77	0.12	1590	75	Wk-17578	1627	33	1380	1540
PL05-BS15	K0532	15050	quartzite	22370	0.57	1.82	2.40	0.06	3.47	0.08	1390	50	Wk-17578	1627	33	1380	1540
PL05-BS16	K0533	15059	quartz	5	0.00	1.72	1.72	0.05	0.53	0.30	250	170	Wk-17576	256	36	140	440
PL05-BS17	K0534	15059	meta-sst	2710	0.58	1.72	2.30	0.06	0.69	0.02	240	15	Wk-17576	256	36	140	440
PL05-BS18	K0535	15062	quartzite	6820	0.34	1.86	2.20	0.05	1.18	0.07	480	35	Wk-17579	698	38	550	670
PL05-BS19	K0536	15063	quartzite	130	0.14	1.77	1.91	0.05	0.23	0.03	60	15	Wk-17580	170	35	-11	280
PL05-BS20	K0537	15068	schist	180	3.26	1.64	4.90	0.30	0.98	0.10	150	25	Wk-17581	168	35	-11	280
PL05-BS21	K0538	15071	quartzite	15330	0.43	1.58	2.01	0.05	0.29	0.01	90	5	Wk-17582	115	33	-11	260
PL05-BS22	K0539	15097	quartzite	780	1.85	1.68	3.52	0.12	3.74	0.08	1010	40	Wk-17583	1059	46	790	1050
PL05-BS23	K0540	15116	quartzite	370	0.70	1.73	2.43	0.07	11.57	0.76	4700	340					
PL05-BS24	K0541	15116	quartz	60	0.05	1.73	1.78	0.05	1.33	0.07	690	45					
PL05-BS25	K0542	15126	quartz	15	0.01	1.89	1.90	0.05	4.15	0.72	2130	390	Wk-17584	587	46	500	640
PL05-BS26	K0543	15126	quartzite	17990	1.98	1.89	3.87	0.14	2.74	0.06	650	30	Wk-17584	587	46	500	640
PL05-BS27	K0544	15154	schist	2930	0.20	1.82	2.02	0.05	0.40	0.08	150	40	Wk-17585	175	34	-11	290
PL05-BS28	K0545	15154	quartzite	250	1.64	1.82	3.46	0.12	1.03	0.04	240	15	Wk-17585	175	34	-11	290
PL05-BS29	K0546	15154	schist	2420	1.58	1.82	3.40	0.15	0.68	0.03	140	10	Wk-17585	175	34	-11	290
PL05-BS30	K0547	15164	quartz	1840	0.25	1.80	2.05	0.05	0.15	0.00	20	5	Wk-17586	395	35	320	500
PL05-BS31	K0548	15164	schist	3530	2.59	1.80	4.39	0.23	1.36	0.05	260	20	Wk-17586	395	35	320	500
PL05-BS32	K0549	15176	meta-sst	950	1.67	1.84	3.51	0.12	2.36	0.07	620	30	Wk-17587	651	34	540	660
PL05-BS33	K0550	15176	quartz	30	0.07	1.84	1.91	0.05	1.83	0.25	900	130	Wk-17587	651	34	540	660
PL05-BS34	K0551	15180	quartz	140	0.03	1.54	1.57	0.05	0.94	0.19	540	120	Wk-17588	883	33	670	800
PL05-BS35	K0552	15180	quartz	610	0.21	1.54	1.75	0.05	0.44	0.02	200	15	Wk-17588	883	33	670	800
PL05-BS36	K0553	15180	meta-sst	1840	0.68	1.54	2.22	0.06	1.44	0.04	600	25	Wk-17588	883	33	670	800
PL05-BS37	K0554	15180	quartz	1	0.01	1.54	1.54	0.05	4.93	23.50	3140	15250	Wk-17588	883	33	670	800

Table 2. Preliminary OSL and ¹⁴C comparison from Poolamacca heat-retainer hearths, in years before AD 1950. Also shown are lithology (meta-sst = meta-sandstone), OSL test dose sensitivity; internal, external and total dose rates; equivalent dose values; uncalibrated ¹⁴C age, maximum and minimum calibrated ¹⁴C age estimates. Note that multiple peaks in ¹⁴C calibrations are not shown.

case for samples classified as quartz. No attempt to relate sample colour or size to the degree of OSL age under-estimation has been undertaken, though careful re-examination of each sample may reveal patterns in this trend. In the future, it may be useful to explore sub-samples or single grains from different depths within individual rocks; surface OSL ages may be expected to be lower than those from central parts for samples which have experienced partial zeroing by light exposure before collection.

Some samples displayed significant IRSL signals (e.g. K0528), although no obvious relationship of IRSL magnitude to OSL age was observed. A brief HF treatment might reduce the IRSL signal, and possibly also improve OSL age agreement.

A wide variation in natural sensitivity of the OSL signal was observed, spanning around 5 orders of magnitude; quartzite sample K0134 had a sensitivity of $79,650 \text{ c.s}^{-1}.\text{mg}^{-1}.\text{Gy}^{-1}$ (Table 1), while quartz sample K554 had one less than $1 \text{ c.s}^{-1}.\text{mg}^{-1}.\text{Gy}^{-1}$ (Table 2). In general, quartz samples had the lowest OSL sensitivities of any lithology, leading to reduced precision in the equivalent dose determination for several samples.

For the preliminary OSL age estimates shown here, the beta dose rate was assumed to originate outside the measured quartz grains, and no alpha dose rate contribution has been included. In Tables 1 and 2, internal dose rate refers to the rock sample, not the quartz grains. These assumptions may require modification in future. Note that if further alpha and beta dose rate contributions were included, the total dose rate would increase, and the estimated OSL age would decrease.

Our preliminary results are very encouraging, and clearly demonstrate the potential of OSL for dating exposed heat-retainer hearths in western NSW. The method requires some further refinement to improve the degree of agreement between OSL and independent chronological control provided by radiocarbon. However, we can now provide provisional answers to the three questions we initially posed:

4. We observe no clear indication of incomplete signal zeroing, though some samples do provide OSL age over-estimates.
5. Some translucent or pale-coloured lithologies provide OSL age under-estimates, suggesting that daylight bleaching occurred while samples lay at the surface.
6. The good agreement between OSL and ^{14}C for many of the samples suggests that complex geometry does not represent a significant obstacle for OSL dating. Most of the samples which provide OSL age estimates not in agreement with ^{14}C are significantly in error, rather than just a little outside the estimated uncertainty limits, which suggests other causes for these errors.

We plan to re-measure these samples after a brief HF treatment to reduce possible feldspar contamination, and to examine the dependence of age on burial depth, internal dose rate, sediment moisture content, and other parameters. We will also examine the role of sample size and colour in controlling surface bleaching. From the large dataset of paired OSL and ^{14}C samples presented here, it will be possible to estimate meaningful values for inter-sample variation beyond the estimated uncertainties, which may be applied to similar OSL age estimates in the future. We will also produce guidance on optimal lithology and sample size to assist efficient collection.

Conclusions

From the data presented here, we are confident that OSL can provide a very useful technique for estimating the age of heat-retainer hearths exposed at the surface in arid Australia. This technique is likely to be popular with Aboriginal groups and heritage managers as it does not require excavation and causes only minimal damage to the hearths. It also requires relatively little laboratory preparation time and chemical treatment, and the OSL measurement time is short. Thus, there are likely to be considerable cost savings compared with radiocarbon dating of hearth charcoal. This method is suitable for application to large numbers of stones, which in turn will lead to meaningful chronologies of landscape occupation.

Acknowledgements

We would like to thank Maureen O'Donnell, Chairperson of the Broken Hill Local Aboriginal Lands Council, who encouraged us to undertake the project, and provided a very warm welcome and support during our stay at Poolamacca. We also thank Raymond O'Donnell and Christine and Tahnee Tester, and other members of the O'Donnell family who worked with us at Fowlers Gap and at Poolamacca, including Bernie, young Bernie, Maxine, Raelene, Latisha, Courtney and Jade O'Donnell, Malcolm McKellar, Peter and Ty Farnham, and Pauly Menz. Bridget Mosley, Margaret Rika-Heke, Irene Wallis, Phil Deacon and John Pickard are thanked for their contributions to the fieldwork. We also thank the University of NSW for access to Fowlers Gap Arid Zone Research Station, and the NSW National Parks and Wildlife Service for permission to excavate hearths and collect hearth stones. Thanks also to Norman Hill at the ANU for laboratory assistance and the Waikato Radiocarbon Laboratory, particularly Alan Hogg and Fiona Petchey, for providing the radiocarbon determinations, and to Jim Feathers for comments on the manuscript. This research was supported in part by AIATSIS grant G2004/6955, an ARC Large Grant to Holdaway and Fanning, and a Macquarie University Research Grant to Fanning.

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