Date List 7: Luminescence dates for Prehistoric and Proto-Historic pottery from the American Southwest

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(Received 25 February 2000; in final form 29 June 2000)

Introduction

This date list presents dates from over 100 ceramic and burned stone samples from prehistoric and historic sites in the American Southwest, analyzed by the luminescence laboratory at the University of Washington from 1994 to 1999. The Southwest has a rich archaeological tradition, in large part because of the remarkable preservation afforded by the generally dry climate. The detailed painted designs on much of the prehistoric pottery, the styles of which have changed rapidly through time, have also allowed a rather finely resolved chronology, tied to a calendrical scale by an abundance of radiocarbon and, particularly, tree ring dates (Blinman, 2000). Nevertheless, there are still pockets of uncertainty in Southwestern ceramic chronology. In the lowland desert region of southern Arizona, the Hohokam cultural sequence has suffered from poor resolution due to inadequacy of tree-ring dating and temporally insensitive ceramics (Dean, 1991). More relevant to this work is the poorly known chronology of the very late prehistoric/early historic record, which has recently gained interest among scholars seeking to understand the ramifications of Spanish contact on native populations (e.g., Raminofsky, 1996) and the impact of the relatively late migration to the region by Apache and Navajo groups (e.g., Towner, 1996).

The dating work reported here has not resulted from any systematic study originating from the laboratory, but rather represents the serendipitous accumulation of dating analyses contracted by a variety of academic and cultural resource management (CRM) organizations. The bulk of the dates are on Navajo ceramics or on late Puebloan ceramics, mostly from northwestern New Mexico, but also included are earlier ceramics from the Colorado Plateau, the desert lowlands of southern Arizona, and the Great Basin. Most of the dates are for pottery, but a few burned rocks from hearths and similar contexts have been included; some dates previously published are not included (e.g. Feathers and Rhode, 1998).

The analyzed ceramics are generally thin-walled (5-7mm), relatively high fired (ca. 800-900°C), and fine textured with inclusions of fine sand or volcanic material. The fine texture has necessitated use of the fine-grain dating technique. Overall the luminescence characteristics of the samples can be described as well behaved. The fabrics are composed of clays that are relatively high in naturally occurring radionuclides (means tabulated for 92 of the ceramics reported here are 12.2 ± 5.4 ppm Th and 4.2 ± 1.7 ppm U), and contain luminescent minerals of high sensitivity. Scatter in growth curves tends to be low, plateaus are generally broad, and anomalous fading is only present in a few sherds. The recovery context is often complex, representing dwellings (various pit structures, adobe room blocks or Navajo "hogans"), middens, or other activity centers, but generally radioactivity does not seem to vary greatly from different areas of the sites. Many of the ceramics were recovered from the surface. This complicates to some degree estimations of the gamma dose rate and increases the contribution from the cosmic dose rate (especially given the high altitude of some regions such as the Colorado Plateau where elevations at sites range up to 2500 m or more). However, we have shown in other contexts that these uncertainties are not greater than those for buried ceramics, particularly, as is often the case, where the timing and rate of burial are unknown (Dunnell and Feathers, 1994). Moisture contents are generally low, because of the relatively dry climate, although there is variation from place to place.

Procedures

The laboratory's procedures have evolved through the years. What follows is a generalized protocol. Sherds are broken to expose a fresh profile, and material then drilled from the center of the cross-section more than 2 mm from either surface, using a tungsten carbide drill bit. To avoid mechanical fragmentation of grains the drill is kept at low speed and material is scraped out mainly using the sides of the drill bit rather than the tip and employing minimum pressure. The material retrieved is ground gently in an agate mortar and pestle, treated with HCl and then settled in acetone for 2 and 20 minutes to separate a 1-8 µm fraction, which is then deposited onto stainless steel discs. TL is measured on a Daybreak reader using a 9635Q photomultiplier through a Corning 7-59 (blue) filter, in N_2 atmosphere, heating at 1°C/s to 450°C. A preheat of 1°C/s to 240°C and then immediate cooling to room temperature precedes each measurement. In earlier analyses, samples were preheated in a separate oven at 70°C for several days, depending to some degree on the amount of fading detected over the first few weeks. Artificial irradiation is provided by a ^{241}Am alpha source, calibrated by the manufacturer (Littlemore Scientific) following Aitken (1985), and a ^{90}Sr beta source, calibrated against a ^{137}Cs gamma source. After irradiation, sample discs are stored for at least one week prior to measurement of the luminescence.

Tests for anomalous fading involve measuring the natural signal on several discs, administering equal alpha irradiations and storing at room temperature for various times up to 8-10 weeks. The irradiations are staggered in time so that all second glows are performed on the same day. The second glows are normalized by the natural signal and the signal from the plateau region plotted against log time. Dating results of any sample showing fading beyond one week are presented as minimums, indicated in the table by italic type. Alpha irradiations were chosen for this test because of convenience in administering the dose. Moreover, for most samples, alphas are a significant contributor to the dose rate. Figure 1 shows examples of sherds displaying fading and no fading.

Paleodose is determined by combining additive dose and regeneration growth curves in the "Australian slide" method (Prescott *et al.*, 1993), using the program developed by David Huntley of Simon Fraser University. Sensitivity changes are corrected using the scale factor (which is a ratio of the two slopes) computed in that program. Where the scale factor is within two standard deviations of one, the program is run assuming no sensitivity change. Fits are either linear or, particularly for younger samples, quadratic. An earlier version of the program used a cubic rather than quadratic fit, although the cubic term for these ceramics was never significant. Dose increments are determined so that the maximum additive dose results in a signal about three times that of the natural and the maximum regeneration dose about five times the natural. A few analyses determined palaeodose by an additive dose extrapolation corrected for supralinearity by the regeneration intercept (this is indicated in the date list table and a footnote gives the ratio of the supralinearity correction to the paleodose for these few samples). One advantage of the slide method is that supralinearity is automatically taken into account, resulting in higher precision. Figure 2 shows two examples of growth curves following the slide procedure, showing samples with more and less scatter.

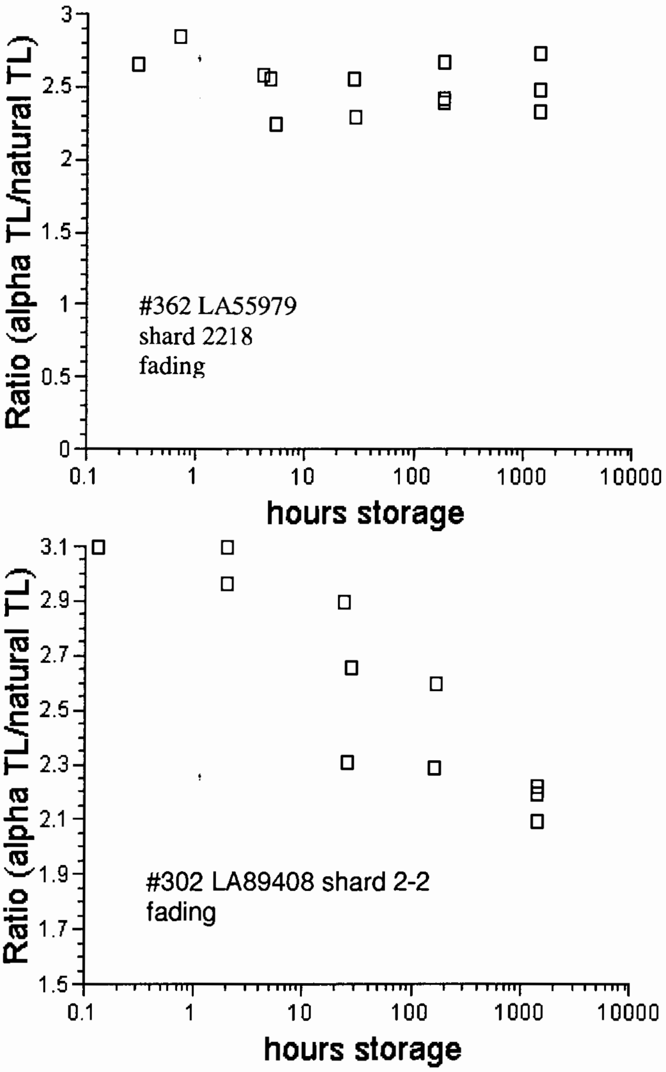

Figure 1. *Examples of anomalous fading results.*
(a) UW362 shows no fading over the 8-week storage time. (b) UW302 shows substantial fading that is not complete by eight weeks.

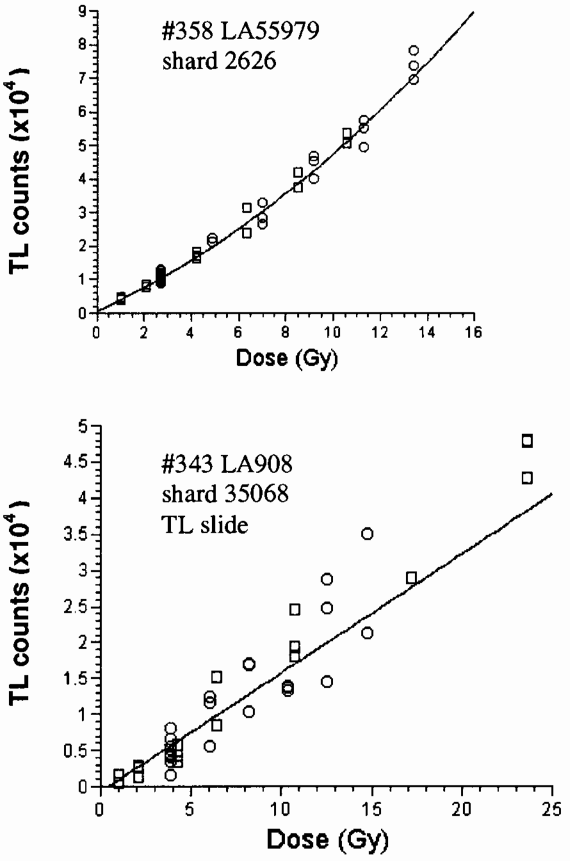

Figure 2. *(a) Quadratic fit to additive dose and regeneration points after the slide procedure for UW358. (b) Linear fit to the same kind of data for UW343, except that the scatter is much greater. In both graphs, the open circles are additive dose points and open squares are regeneration points.*

A plateau region is determined by calculating the paleodose at temperature increments between 240° and 450°C and determining over which temperature range the values do not differ significantly. This plateau region is compared with a similar one constructed for b-values, and the smaller of the two plateaus defines the region over which the signal is integrated for final determinations. Some earlier analyses defined the plateau on the basis of dose intercepts for first glows (alphas and betas) and second glows, but this more conservative approach was abandoned once more advanced slide software was obtained. Figure 3 shows some typical plateau plots.

Where the size of the sherd prevents a full multi-aliquot analysis, the palaeodose is determined by the SARA technique (Mejdahl and Bøtter-Jensen, 1994). Several aliquots are given additive doses, and then after heating to 450°C are given regeneration doses on the order of magnitude of the natural signal or the natural plus added dose signal. The apparent palaeodose is determined by regeneration measurements with each aliquot. These are plotted against the original additive dose and a linear extrapolation to the dose axis provides the correct palaeodose. We have found this method to be less precise than the multiple aliquot procedure.

A summary of procedures for deriving equivalent dose is given in Table 1.

Alpha efficiency is determined by comparing the slopes of additive dose curves built using alpha and beta irradiations. The ratio of the slopes is taken as the b-value., and this is determined by scaling the alpha curve to the beta curve using Huntley's slide program (Lian et al., 1995). A b-value variation of this program has been developed by Prof. Huntley.

Radioactivity is measured by alpha counting in conjunction with flame photometry for ^{40}K. Samples for alpha counting (for sherds, using fragments remaining after material has been removed for luminescence measurements) are crushed in a mill to a fine powder, packed into plexiglass containers with ZnS:Ag screens, and sealed for one month before counting. The pairs technique is used to separate the U and Th decay series. For flame photometer measurements, samples are dissolved in HF and other acids and analyzed by a Jenway flame photometer. K concentrations for each sample are determined by bracketing between standards of known concentration.

Both the sherd and an associated soil sample are measured for radioactivity. Additional soil samples are analyzed where the environment is complex, and gamma contributions determined by gradients (after Aitken, 1985: appendix H). The cosmic ray dose is determined after Prescott and Hutton (1988). Radioactivity concentrations are translated into dose rates following, most recently, Adamiec and Aitken (1998).

Water absorption values for sherds are determined by comparing the saturated and dried weights. For the climates typical of the Southwest, which is dry much of the year but has seasonal rain in late summer and snow at higher elevations in winter, moisture values are taken to be about 30± 20 to 50±20 percent of saturated values, depending on information provided by the archaeologist. Soil moisture contents are determined largely on the basis of texture, with values of about 6 percent for sands and 11-15 percent for siltier substrates (Brady, 1974:196).

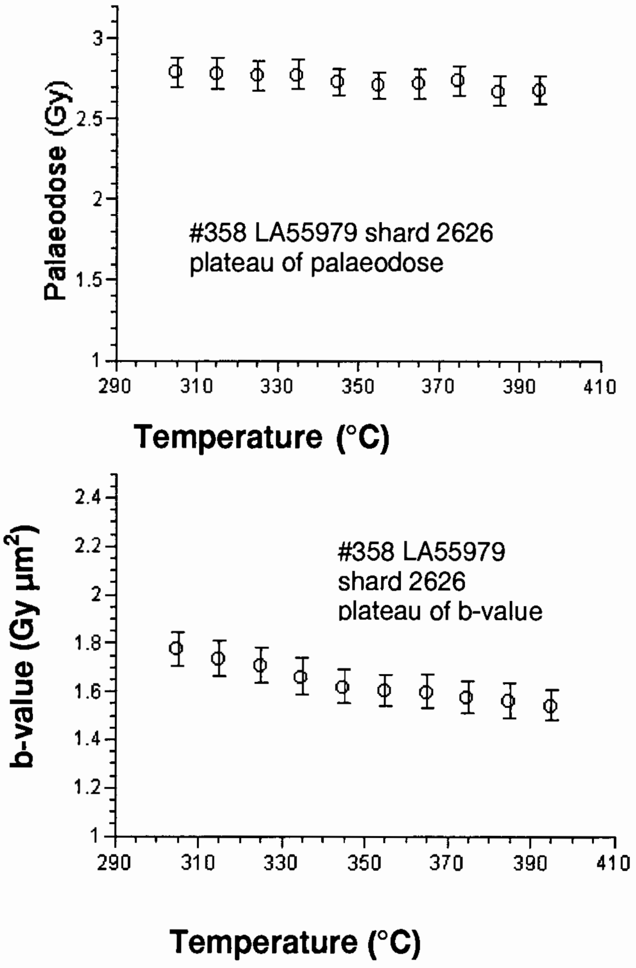

Figure 3. Plateau test for UW358 showing results for (a) equivalent dose and (b) b-value.

Accuracy and precision

Tests for accuracy are not a straight-forward task because seldom are the dating events precisely the same for luminescence and independent methods. We addressed this problem in a comparison of TL and tree-ring dates obtained from several short occupation Navajo sites in northwestern New Mexico (Dykeman *et al.*, 2000). Direct comparisons were available from 12 sites, from which 15 TL dates were obtained. The tree-ring dates were considered high quality not only because of a close match with the reference curve but because they were derived from wood containing either the outer most ring or significant amounts of sapwood. Stumps from cut limbs were available at some sites. In these cases the cutting did not kill the tree, which continued to grow (even to the present) and protected the stump rings from weathering. Distinctive axe scars, attributed to early Navajos, suggested these trees were cut during occupation. The precision of these dates was taken to be nearly 1 year. Using a 1 σ confidence interval (average 70±18 years) for the TL dates, only four of the 15 dates agreed with corresponding tree ring dates.

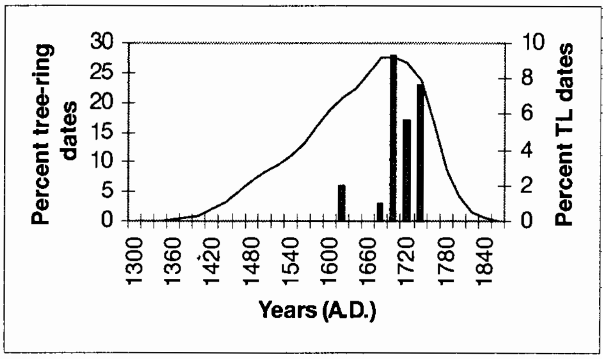

Figure 4. Comparison of aggregate TL and tree-ring dates, as explained in the text.

However, tree-rings date the cutting of a tree, usually for construction, an event that may not correspond closely with firing of the pottery. Dates of these events may differ significantly at any one site, although the differences should average out on a regional scale. Indeed, the aggregate distributions from all sites (Figure 4) show a much closer correspondence. In this figure the TL dates are treated as normal probability distributions, which are summed at any given point. The distributions from the two techniques are similar with a main node around AD 1700, although an earlier minor node apparent in the tree-ring data is less defined in the TL distribution. If the TL distribution is deconvoluted by the two ceramic types represented (Figure 5), the bimodality of one of the types closely matches the bimodality in the tree-ring dates, while both types contribute to the main node. Terminating the probability distributions of TL dates for both ceramic types at the 75th percentile produces ranges (AD 1640-1780 for Gobernador Polychrome and AD 1520-1740 for Dinetah Gray) remarkably close to the range of production estimated for both types by several radiocarbon and tree-ring dates from across the region

(AD 1630-1775 for Gobernador Polychrome and AD 1540-1800 for Dinetah Gray). These results underscore the difficulty in directly comparing dating methods that address different events, but also show that luminescence provides some chronological information -- on ceramic production -- that may not be as easily obtainable from tree-rings or radiocarbon. These data are presented in more detail by Dykeman *et al.* (2000). In a more recent study (Dykeman, 2000), a comparison of tree-ring dates (used as the standard) with 14 TL dates (numbers 357-370 in this date list) and several radiocarbon dates, all obtained from Morris I, a large Navajo site in northwestern New Mexico, concluded TL provided better accuracy and even better precision than radiocarbon. The latter suffers in this region from old wood effects and for this time period from multiple intercepts on the calibration curve.

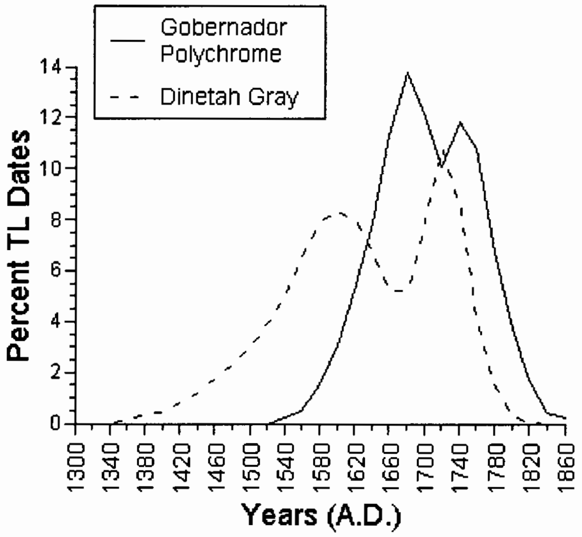

Figure 5. *Distribution of TL dates by ceramic type.*

Variable precision in the dates reflects in large part the scatter about the growth curves. As our fitting procedures and other aspects of the protocol have improved through the years, the precision obtainable has improved and become less variable. The mean, standard deviation and median of percent errors for all the dates are 12.8, 8.2 and 10.2 respectively, while the same numbers for dates obtained since 1996 are 10.7, 3.6, and 9.5 respectively. The errors reported were computed using an Excel spreadsheet developed in this laboratory and modeled after Aitken (1985: Appendix B). The errors, computed at 1σ, include both random and systematic contributions.

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Reviewer
I.K. Bailiff

DATE LIST 7: LUMINESCENCE DATES ON PREHISTORIC AND PROTO-HISTORIC POTTERY FROM THE AMERICAN SOUTHWEST

The data presented include procedures for determining palaeodose (Table 1), information about the samples and submitting organizations (Table 2), notes on abbreviations used, and the main date list (Table 3).

***Table 1**: Procedures for determining palaeodose*

Procedure	**Steps**
TL slide (TL1)	1. Aliquot allocation and dosing: 1-15, natural then alpha dose for fading; 16-30 natural, then regeneration doses; 31-45 natural plus added beta; 46-60 natural plus added alpha. Number of aliquots adjusted for smaller samples. 2. Preheat 240°C @ 1°C/s, and cool. 3. Heat to 450°C @ 1°C/s to measure TL, repeat for background 4. Use slide program to determine plateau. 5. Integrate over plateau region and use slide to determine palaeodose (D_E) and alpha efficiency.
TL additive dose (TL2)	1. Steps 1-3 of TL1 2. Use additive dose extrapolation to determine plateau 3. Integrate over plateau region and determine D_E by adding intercepts of additive dose and regeneration. Alpha efficiency determined as in TL1
SARA	1. Make as many aliquots as possible: some naturals, some additive dose (beta and alpha). Use same preheat and temperature regime as TL1. 2. Follow TL1 steps as much as possible, and determine a regeneration dose that yields a TL signal close in magnitude to the natural 3. Use that dose plus the additive dose to determine a regeneration dose for various additive dose discs 4. Use additional regeneration doses as needed to bracket the natural or additive dose signal. 5. Determine apparent D_E of natural and additive dose discs by interpolation 6. Use apparent D_E as function of original additive dose to extrapolate D_E 7. If D_E from SARA and D_E from the limited number of discs for TL1 agree, use weighted average
OSL	1. Use single aliquot protocol, after Duller (1995). Steps are preheat, natural OSL, dose, preheat, OSL, dose, preheat, OSL, etc., using at least 5 dose increments, then several preheats and OSL measurements without dose to correct for signal loss at each step. 2. Build additive dose and regeneration curves for different aliquots and combine using slide after normalization by the natural signal. Regeneration followed heating to 450°C 3. Preheat at each incremental step at 220°C for five minutes @1°C/s 4. OSL measured at 100°C using green light from filtered quartz-tungsten halogen lamp (550 ± 20nm). Stimulate for 5s at reduced lamp intensity.

***Table 2:** Sample information*

Sample reference	Sample Type	Region	Contracting Agency	References
344-346,348, 350-351, 430	Ute ceramics	Colorado Plateau (N. Mex. and Colo.)	Alpine Archaeological Consultants, Montrose, CO	Reed and Zier, 2000
349	Navajo ceramic			
347	Puebloan ceramic			
230-233	Hohokam ceramics	Tonto and Phoenix Basins (Ariz.)	Arizona State University, Tempe	Rice, 1998
135-138	Navajo ceramics	Colorado Plateau (N.Mex.)	Cultural Resources Management Consultants, Farmington, NM	
111-112	Numic brownware ceramics	Great Basin (Nev. and Utah)	Desert Research Institute, Reno, NV	Rhode, 1994; Feathers and Rhode, 1998
161	Puebloan pottery	Colorado Plateau (N.Mex.)	Mariah Associates, Albuquerque, NM	
119-120	Burned sandstone (Archaic period)	Colorado Plateau (N. Mex. and Ariz.)	Navajo Nation Archaeology Department, Farmington, NM	Dykeman and Wharton, 1996; Dykeman *et al.*, 2000; Dykeman, 2000
253-254	Burned sandstone (Navajo period)			
190,192, 359-361	Puebloan pottery			
191	Burned basalt			
193-194	Basketmaker pottery			
142-147. 236-252,328-333, 357-358, 362-370, 463	Navajo pottery			
104	Burned sandstone	Colorado Plateau N. Mex.)	San Juan College, Farmington, NM	Kotyk *et al.*, undated
105-106, 303, 312	Basketmaker-Puebloan pottery			
107	Burned daub			
149-153, 302, 304-311, 313-314	Navajo pottery			
113-114, 164-166, 342-343, 372-373	Proto-historic Puebloan pottery	Chama Valley, N. Mex.	University of New Mexico, Albuquerque	Ramenofsky, 2000; Ramenofsky and Feathers, 2000
408-413	Spanish colonial ware	Comanche Springs, NM		

Entry#	Luminescence Single dates[1]	List Ref	State/Site/sherd ref.	C	P Gy	m2/m1	Procedure[2]	TotDR Gy/ka	b val Gy μm^2	α %	β %	γ %	cos %	W_s %	W_e %	Z cm
68.1	1684±138 AD	WA94TLfg104	NM/LA79384/27	os	1.01±0.45	0.72±0.01	TL2;L;70°C7d;295-350°C	3.26±0.24	0.95±0.46	18.4	45.7	26.4	9.8	4	16	20
68.2	990±104 AD	WA94TLfg105	NM/LA79411/12	h	4.28±0.40	1	TL1;L;70°C30d;310-350°C	4.26±0.16	1.00±0.14	21.4	46.9	24.6	7.3	6	12	20
68.3	759±148 AD	WA94TLfg106	NM/LA79411/15	h	6.22±0.71	1	TL1;L;70°C7d;280-340°C	5.03±0.18	0.93±0.11	19.5	47.9	26.8	6	8	12	20
68.4	1556±43 AD	WA94TLfg107	NM/LA80474/30	os	2.61±0.20	1	TL1;L;70°C7d;320-360°C	5.95±0.36	1.70±0.26	34.8	36.3	23.4	5.5	7	12	10
68.5	1598±81 AD	WA94TLfg111	NV/26Ny3621/321	rs	3.32±0.68	0.83±0.01	TL1;L;70°C61d;320-360°C	8.38±0.38	0.62±0.19	20.6	47.9	27.2	4.3	0	0	32
68.6	1877±34 AD	WA94TLfg112	UT/42To13/67	rs	1.01±0.22	0.75±0.01	TL2;L;70°C7d;200-260°C	8.60±1.90	1.80±1.04	47.4	41.9	8.6	2.1	0	0	15
68.7	1432±73 AD	WA94TLfg113	NM/LA297/856	o	3.40±0.41	0.83±0.08	TL1;Q;240°C;240-340°C	6.04±0.28	1.69±0.14	36.9	47.2	9.8	6.1	11	12	0
68.8	1531±39 AD	WA94TLfg114	NM/LA297/2060	o	2.75±0.20	0.65±0.03	TL1; Q;240°C;320-380°C	5.93±0.25	1.16±0.07	27.7	54.6	11.6	6.2	11	12	0
68.9	1901±350 BC	WA94TLqi119	NM/LA71781/1073	h	15.61±1.35	1	TL1;L;180°C5m;320-350C[3]	4.01±0.10	1.96±0.76	0.7	64.1	28.9	6.2	2	6	60
68.10	1430±321 BC	WA94TLqi120	NM/LA71782/639	h	10.90±0.99	1	TL1;L;none;320-350°C	3.18±0.07	1.96±0.76	1.6	55.3	35.2	7.5	4	15	55
68.11	1654±90 AD	WA94TLfg135	NM/LA83096/230	os	2.20±0.53	0.78±0.01	TL2;L;70°C4d;280-340°C	6.46±0.73	2.21±0.78	39.8	39.2	16.6	4.5	5	16	20
68.12	1640±75 AD	WA94TLfg136	NM/LA83096/227b	os	1.94±0.31	1	TL1;L;70°C7d;250-335°C	5.48±0.77	2.11±1.20	33.9	40	20.6	5.3	4	16	20
68.13	1664±78 AD	WA94TLfg137	NM/LA83096/227a	os	1.94±0.38	1	TL1;L;70°C7d'260-350°C	5.88±0.77	2.53±1.22	37.1	38.8	19.2	4.9	3	16	20
68.14	1686±50 AD	WA94TLfg138	NM/LA83096/227c	os	2.07±0.29	0.88±0.01	TL1;L;70°C21d;230-370°C	6.72±0.56	2.28±0.60	39.4	39	17.1	4.3	5	16	20
68.15	1745±19 AD	WA95TLfg142	NM/LA105483/3	o	1.99±0.14	0.82±0.03	TL1;L;70°C5d;270-350°C	7.97±0.23	1.64±0.07	37.5	46.7	10.8	5	1	6	0
68.16	1624±32 AD	WA95TLfg143	NM/LA105530/15	o	2.59±0.21	1.12±0.05	TL1;L;70°C5d;260-310°C	6.98±0.22	1.77±0.08	37.8	45.3	11	5.7	2	6	0
68.17	1766±30 AD	WA95TLfg144	NM/LA105428/5	o	1.78±0.22	1.30±0.01	TL1;C;70°C5d;270-330°C	7.77±0.28	1.66±0.13	36	43.5	15.3	5.1	4	6	0
68.18	1665±50 AD	WA95TLfg145	NM/LA105479/1	os	1.16±0.17	1	TL1;L;70°C5d;270-320°C	3.52±0.12	0.99±0.11	14.2	58.8	15.3	11.4	1	6	0
68.19	1718±21 AD	WA95TLfg146	NM/LA105938/31	o	1.69±0.12	0.69±0.03	TL1;L;70°C7d;280-390°C	6.10±0.18	1.53±0.06	30.2	42.6	20.7	6.6	2	6	0
68.20	1734±32 AD	WA95TLfg147	NM/LA83529/1	m	1.42±0.17	1.37±0.09	TL1;L;70°C7d;270-400°C	5.44±0.18	1.69±0.11	32	48	13.1	7.4	3	6	0
68.21	1607±99 AD	WA95TLfg149	NM/LA89998/238-4	os	2.21±0.53	0.86±0.01	TL2;L;70°C21d;270-330°C	5.70±0.50	1.82±0.71	29.3	43.9	20.9	6	4	11	15
68.22	1631±39 AD	WA95TLfg150	NM/LA89998/406-4	os	2.03±0.18	1	TL1;L;70°C21d;260-300°C	5.57±0.34	1.84±0.43	31.6	42.7	19.7	6.1	4	11	15
68.23	1476±55 AD	WA95TLfg151	NM/LA89998/681-9	rf	3.18±0.24	1	TL1;L;70°C21d;260-340°C	6.13±0.45	2.30±0.59	35.6	38.7	20.2	5.5	4	11	15
68.24	1670±98 AD	WA95TLfg152	NM/LA89998/251-6	o	1.87±0.55	0.82±0.01	TL2;L;70°C21d;260-340°C	5.75±0.42	1.49±0.48	28.3	45.6	20.2	5.9	4	11	15
68.25	1736±28 AD	WA95TLfg153	NM/LA89998/268-4	o	1.39±0.13	1	TL1;L;70°C5d;270-310°C	5.34±0.29	1.74±0.37	28.8	41	23.8	6.4	5	11	15
68.26	1353±143 AD	WA95TLfg161	NM/LA100419/660	ps	3.76±0.80	0.78±0.01	TL1;L;70°C3d;300-340°C	5.86±0.42	0.90±0.35	22	59.6	14.7	3.6	5	16	125
68.27	1819±27 AD	WA95TLfg164	NM/LA298/20710	o	0.80±0.12	1	TL1;Q;240°C;320-390°C	4.55±0.19	1.43±0.13	29.5	51.4	11	8.1	7	12	0
68.28	1777±16 AD	WA95TLfg165	NM/LA298/20708	o	1.29±0.08	1	TL1;L;240°C;310-380°C	5.92±0.22	1.60±0.08	37.8	47	9	6.3	6	12	0
68.29	1854±95 AD	WA95TLfg166	NM/LA298/20703	o	0.77±0.52	na	SARA;L;240°C;310-380°C	5.47±0.22	1.40±0.15	29.8	53.4	10.2	6.8	8	12	0
68.30	881±86 AD	WA96TLfg190	AZ/I-26-23/548	m	10.6±0.65	1	TL1;C;240°C;260-290°C	9.51±0.45	1.59±0.17	44.4	43.3	10	2.3	7	20	80
68.31	4115±807 BC	WA96TLfg191	AZ/I-26-30/297	h	48.5±6.3	0.53±0.07	TL1;C;240°C;280-320°C	7.94±0.19	0.98±0.09	20.7	57.9	17.6	3.8	1	6	30
68.32	897±83 AD	WA96TLfg192	AZ/I-26-37/266	h	5.04±0.35	1.10±0.06	TL1;C; 240°C;290-310°C	4.59±0.14	1.14±0.10	19.2	49.7	25.5	5.4	3	6	16
68.33	956±94 AD	WA96TLfg193	AZ/I-25-47/515	ps	5.41±0.45	1	SARA;C;240°C;300-330°C	5.20±0.18	0.83±0.06	27.7	49.6	17.5	5.2	9	12	35
68.34	438±138 AD	WA96TLfg194	AZ/I-25-47/655	ps	12.1±0.76	1	TL1;C; 240°C;270-320°C	7.77±0.49	1.48±0.26	41.7	42.9	11.8	3.6	10	12	38
68.35	*1321±145 AD*	WA96TLfg230	AZ/U-4-4/42461	ms	2.37±0.50	0.41±0.07	TL1;L; 240°C;280-340°C	3.51±0.14	1.58±0.19	16	40.5	35.9	7.7	4	6	23
68.36	*1261±82 AD*	WA96TLfg231	AZ/U-4-33/42455A	m	2.50±0.23	1	TL1;C; 240°C;290-340°C	3.40±0.22	2.30±0.50	27.4	35.6	28.5	8.5	8	12	5
68.37	1374±58 AD	WA96TLfg232	AZ/U-4-33/42455B	m	5.18±0.43	0.76±0.03	TL1;C; 240°C;280-340°C	8.33±0.34	1.48±0.06	38.1	44.5	14	3.5	7	12	5
68.38	1308±56 AD	WA96TLfg233	AZ/U-9-41/196	ps	3.26±0.23	1	TL1;L; 240°C;320-400°C	4.74±0.19	0.86±0.04	21.9	51.5	21.1	5.5	5	6	10
68.39	*1681±26 AD*	WA97TLfg236	NM/LA106203/27	m	1.76±0.09	1	TL1;C; 240°C;290-420°C	5.57±0.19	1.56±0.04	40.6	41.1	11.1	7.2	3	6	0
68.40	1569±41 AD	WA97TLfg237a	NM/LA105475/48	o	2.10±0.16	1	SARA;L; 240°C;280-420°C	4.90±0.16	1.00±0.10	23.9	45.7	22.9	7.3	2	6	10
68.41	1489±55 AD	WA97TLfg237b	NM/LA105475/48	o	1.96±0.18	1	SARA;C; 240°C;310-400°C	3.86±0.13	1.04±0.11	16.6	45.9	28	9.3	3	6	10
68.42	1685±28 AD	WA97TLfg238	NM/LA83529/4	m	2.19±0.13	1	SARA;C; 240°C;330-410°C	7.02±0.31	1.41±0.12	34.2	45.4	15.1	5.3	2	6	9
68.43	1597±66 AD	WA97TLfg239	NM/LA79456/70	o	2.06±0.31	0.86±0.09	SARA;C; 240°C;320-400°C	5.15±0.19	1.16±0.08	27.8	42.9	21.9	7.4	3	6	8

Entry#	Luminescence Single dates	List Ref	State/Site/sherd ref.	C	P Gy	m2/m1	Procedure	TotDR Gy/ka	b val Gy µm²	α %	β %	γ %	cos %	W_s %	W_e %	Z cm
68.44	1615±38 AD	WA97TLfg240	NM/LA105630/33	m	1.70±0.14	1	TL1;C;240°C;290-340°C	4.49±0.15	1.11±0.11	24.5	47.9	18.3	8.5	2	6	9
68.45	1612±39 AD	WA97TLfg241	NM/LA105428/19	o	1.80±0.14	1	SARA;C;240°C;340-390°C	4.68±0.17	0.80±0.07	18.8	45.3	27.6	8.3	4	6	4
68.46	1661±27 AD	WA97TLfg242	NM/LA105929/20	o	1.96±0.10	1	SARA;C;240°C;350-390°C	5.84±0.21	1.12±0.05	26.4	51.9	14.9	7	3	6	0
68.47	1649±39 AD	WA97TLfg243	NM/LA110278/8	m	1.65±0.15	1	SARA;C;240°C;320-380°C	4.74±0.20	1.31±0.17	30.6	40.5	20.9	8.2	3	6	4
68.48	*1592±42 AD*	WA97TLfg244	NM/LA105930/21	m	1.54±0.13	1	SARA;C;240°C;330-390°C	3.80±0.14	1.04±0.09	24.7	40.3	25	10.3	3	6	5
68.49	*1676±22 AD*	WA97TLfg245	NM/LA106199/43	m	2.23±0.08	1	TL1;C; 240°C;240-310°C	6.94±0.21	1.31±0.07	31.6	50.6	12.2	5.6	2	6	3
68.50	*1726±24 AD*	WA97TLfg246	NM/LA106168/10	rf	1.17±0.08	0.76±0.03	TL1;C; 240°C;300-350°C	4.32±0.12	0.98±0.04	20.6	56.3	13.7	9.3	2	6	0
68.51	1491±41 AD	WA97TLfg251	NM/LA55836/8	ms	3.66±0.18	1	TL1;C; 240°C;380-420°C	7.23±0.27	1.07±0.10	34.6	49.9	9.8	5.5	3	6	0
68.52	1753±43 AD	WA97TLfg252	NM/LA55836/12	ms	1.49±0.13	0.76±0.02	TL1;C; 240°C;340-380°C	6.11±0.18	1.32±0.05	31.3	51.9	10.3	6.5	2	6	0
68.53	1535±49 AD	WA97TLqi253	NM/LA11196/389	rs	1.40±0.13	1.28±0.15	TL1;L; 240°C;300-330°C	3.03±0.11		1.7	51.8	34	12.2	1	6	10
68.54	17271± 4361 BC	WA97TLqi254	NM/LA11196/223	rf	61.2±13.3	2.33±0.59	TL1;L; 240°C;250-380°C	3.18±0.11		4.4	54.4	30.5	10.4	1	6	30
68.55	*1528±36 AD*	WA98TLfg302	NM/LA89408/2-2	o	2.25±0.15	1	TL1;C; 240°C;280-350°C	4.80±0.17	1.55±0.05	35.2	41.7	14.8	8.3	2	6	0
68.56	713±91 AD	WA98TLfg303	NM/LA89867/4-1	os	6.13±0.38	1	TL1;C; 240°C;340-370°C	4.77±0.16	0.92±0.04	23.5	50.3	18	8.4	4	6	0
68.57	*1551±33 AD*	WA98TLfg304	NM/LA89867/1-1	o	1.86±0.12	1	TL1;C; 240°C;320-390°C	4.17±0.14	1.10±0.05	23.5	47.5	19.4	9.6	3	6	0
68.58	1622±51 AD	WA98TLfg305	NM/LA112170/1-1	o	2.53±0.32	0.66±0.09	TL1;L; 240°C;310-360°C	6.75±0.33	1.05±0.15	35	44.4	14.5	5.9	3	6	0
68.59	1424±47 AD	WA98TLfg306	NM/LA114877/2-1	o	3.37±0.25	0.83±0.06	TL1;L; 240°C;330-370°C	5.87±0.21	1.47±0.08	26.7	50.1	16.2	7	4	6	0
68.60	1636±29 AD	WA98TLfg307	NM/LA89867/2-1	m	1.79±0.13	1	TL1;C; 240°C;330-380°C	4.97±0.19	1.44±0.07	32.4	46.1	13.3	8	4	6	0
68.61	1609±73 AD	WA98TLfg308	NM/LA114840/1-2	o	1.79±0.33	0.77±0.09	TL1;C; 240°C;280-390°C	4.60±0.18	1.62±0.09	34.3	41.5	16.1	8.3	3	12	0
68.62	*1681±28 AD*	WA98TLfg309	NM/LA114961/1-2	o	1.54±0.12	1	TL1;C; 240°C;320-370°C	4.86±0.21	1.65±0.17	33.7	42.8	15.2	8.4	3	6	0
68.63	1703±22 AD	WA98TLfg310	NM/LA114962/1-1	o	1.32±0.09	0.90±0.03	TL1;C; 240°C;240-350°C	4.48±0.15	1.41±0.04	30.4	46.2	14.1	9.2	3	6	0
68.64	1739±23 AD	WA98TLfg311	NM/LA112170/2-1	o	1.62±0.13	0.82±0.04	TL1;C; 240°C;300-370°C	6.26±0.23	1.76±0.08	37.7	42	13.9	6.4	3	6	0
68.65	638±139 AD	WA98TLfg312	NM/LA114932/2-2	m	6.76±0.51	1	TL1;L; 240°C;350-370°C	4.97±0.21	1.28±0.14	33.6	44.1	14.3	8.2	3	6	0
68.66	1679±58 AD	WA98TLfg313	NM/LA112171/8-2	m	1.30±0.23	1	TL1;L; 240°C;320-370°C	4.07±0.18	1.36±0.14	29	45	16.2	9.8	4	6	0
68.67	1716±29 AD	WA98TLfg314	NM/LA114932/4-2	m	1.57±0.15	0.70±0.05	TL1;L; 240°C;300-350°C	5.57±0.24	1.80±0.10	40.8	37.2	14.7	7.4	4	6	0
68.68	1448±64 AD	WA98TLfg328	NM/LA79469/280	o	4.08±0.44	1.59±0.13	TL1;L; 240°C;340-400°C	7.42±0.31	1.97±0.18	39.6	40.3	15.1	5	2	6	10
68.69	1596±31 AD	WA98TLfg329	NM/LA79469/335	os	3.49±0.24	1	TL1;C; 240°C;330-380°C	8.69±0.28	1.95±0.07	42.9	41.7	11.3	4.3	2	6	10
68.70	1606±45 AD	WA98TLfg330	NM/LA78178/88	os	3.10±0.33	0.74±0.05	TL1;C; 240°C;250-310°C	7.91±0.37	2.06±0.16	48.8	31.6	15.7	4	3	6	30
68.71	1646±42 AD	WA98TLfg331	NM/LA78178/174	m	1.61±0.18	1.30±0.13	TL1;L; 240°C;250-310°C	4.57±0.18	2.31±0.15	39.2	33.5	20.8	6.6	2	6	40
68.72	1387±103 AD	WA98TLfg332	NM/LA78178/328	os	4.67±0.77	1	TL1;L; 240°C;230-390°C	7.64±0.29	1.61±0.13	37.6	43.1	15.3	3.9	3	6	40
68.73	1707±29 AD	WA98TLfg333	NM/LA78178/112	m	1.99±0.18	0.74±0.08	TL1;L; 240°C;300-380°C	6.84±0.28	1.54±0.15	37.6	41.1	16.5	4.8	3	6	20
68.74	1578±51 AD	WA98TLfg342	NM/LA908/35068	o	3.09±0.33	0.66±0.06	TL1;L; 240°C;260-320°C	7.35±0.44	1.56±0.15	38.1	48	8.8	5.2	8	12	0
68.75	1323±125 AD	WA98TLfg343	NM/LA908/35058	o	4.00±0.70	0.45±0.08	TL1;L; 240°C;300-410°C	5.93±0.35	1.28±0.26	31.2	51.8	10.6	6.4	9	12	0
68.76	1503±42 AD	WA98TLfg344	CO/5MN4270/211	o	3.45±0.19	0.84±0.05	TL1;L; 240°C;310-370°C	6.97±0.26	1.56±0.08	37.3	44.8	12.6	5.3	4	12	3
68.77	1411±84 AD	WA98TLfg345	CO/5MN4253/4209	o	2.64±0.34	na	SARA; 240°C;240-320°C	4.50±0.20	1.41±0.13	31.3	44.2	16.7	8	4	12	6
68.78	1576±68 AD	WA98TLfg346	CO/5ME4970/247	h	2.01±0.27	na	SARA; 240°C;300-380°C	4.77±0.34	1.54±0.29	30.2	39.4	22.6	7.8	3	12	4
68.79	961±110 AD	WA98TLfg347	CO/5MN4270/222	o	7.37±0.63	na	SARA; 240°C;280-380°C	7.11±0.26	1.71±0.08	39.4	42.9	12.5	5.1	4	12	5
68.80	*1778±33 AD*	WA98TLfg348	CO/5MN4253/254	o	1.01±0.13	na	SARA; 240°C;260-340°C	4.59±0.24	1.46±0.09	31.2	44.9	16.3	7.6	4	12	8
68.81	1616±36 AD	WA98TLfg349	NM/LA86094/208	o	1.98±0.12	0.67±0.03	TL1;C;240°C;320-410°C	5.18±0.24	2.08±0.10	34.2	44.4	14.7	6.9	4	12	4
68.82	1714±45 AD	WA98TLfg350	CO/5MN4253/240	o	1.45±0.20	na	SARA;240°C;270-350°C	5.11±0.32	1.71±0.28	36.4	43.1	13.7	7	4	12	6
68.83	1509±53 AD	WA98TLfg351	CO/5MN2628/255	o	2.09±0.18	na	SARA;240°C;280-380°C	4.27±0.17	1.71±0.09	26.9	45	19.2	8.9	3	12	15
68.84	*1678±32 AD*	WA99TLfg357	NM/LA55979/1987	os	2.14±0.02	0.81±0.05	TL1;Q; 240°C;300-400°C	6.66±0.23	1.83±0.08	37.1	39	18.8	5.1	3	6	20
68.85	1567±30 AD	WA99TLfg358	NM/LA55979/2626	o	2.78±0.17	1	TL1;Q; 240°C;340-390°C	6.44±0.20	1.59±0.07	34.2	42.5	18.2	5.3	3	6	20
68.86	788±90 AD	WA99TLfg359	NM/LA55979/985	ps	7.35±0.47	1	TL1;Q; 240°C;290-410°C	6.08±0.23	1.50±0.07	31.9	43.4	20.7	3.9	3	6	150

Entry#	Luminescence Single dates	List Ref	State/Site/sherd ref.	C	P Gy	m2/m1	Procedure	TotDR Gy/ka	b val Gy μm^2	α %	β %	γ %	cos %	W_s %	W_e %	Z cm
68.87	1157±77 AD	WA99TLfg360	NM/LA55979/1036	ps	4.54±0.38	0.84±0.04	TL1;Q;240°C;270-310°C	5.39±0.20	1.67±0.05	33.6	40.6	21.3	4.5	3	6	150
68.88	1021±68 AD	WA99TLfg361	NM/LA55979/1035	ps	5.47±0.33	1	TL1;Q;240°C;280-300°C	5.60±0.19	1.65±0.06	31.4	40.5	23.4	4.3	3	6	150
68.89	1510±39 AD	WA99TLfg362	NM/LA55979/2218	os	2.20±0.16	1.22±0.07	TL1;Q;240°C;270-400°C	4.50±0.16	1.32±0.05	22.2	47.3	22.7	7.6	4	6	20
68.90	1591±31 AD	WA99TLfg363	NM/LA55979/2299	os	2.57±0.17	1	TL1;Q;240°C;300-370°C	6.30±0.23	1.77±0.07	35.9	41.9	17	5.4	3	6	20
68.91	1557±41 AD	WA99TLfg364	NM/LA55979/2413	os	2.36±0.20	0.87±0.05	TL1;Q;240°C;320-380°C	5.34±0.18	1.79±0.07	32	42.3	19.1	6.4	3	6	20
68.92	1627±31 AD	WA99TLfg365	NM/LA55979/3205	os	1.56±0.07	1	TL1;Q;240°C;340-380°C	5.27±0.18	1.96±0.15	28.8	46.1	18.6	6.5	4	6	20
68.93	1552±44 AD	WA99TLfg366	NM/LA55979/3101	os	3.05±0.27	1	TL1;Q;240°C;285-385°C	6.82±0.28	1.30±0.11	37.1	40.3	17.6	5	4	6	20
68.94	1559±51 AD	WA99TLfg367	NM/LA55979/1889	os	2.06±0.22	0.85±0.06	TL1;Q;240°C;260-400°C	4.68±0.21	1.51±0.09	24.8	45.1	23.1	7.3	3	6	20
68.95	1619±42 AD	WA99TLfg368	NM/LA55979/2762	os	1.92±0.20	0.66±0.05	TL1;Q;240°C;280-410°C	5.05±0.20	1.71±0.09	34.9	40.6	17.8	6.7	4	6	20
68.96	1527±39 AD	WA99TLfg369	NM/LA55979/2601	os	2.70±0.20	1	TL1;Q;240°C;320-400°C	5.72±0.21	1.70±0.07	32.7	42.1	19.1	5.9	2	6	20
68.97	1626±34 AD	WA99TLfg370	NM/LA55979/2649	os	2.00±0.16	0.75±0.05	TL1;L;240°C;260-420°C	5.37±0.24	1.64±0.10	33.1	40.2	20.3	6.3	4	6	20
68.98	1680±27 AD	WA99TLfg372	NM/LA908/35062	o	2.08±0.15	1	TL1;L;240°C;310-360°C	6.55±0.30	1.68±0.14	35.6	49.6	9	5.8	10	12	0
68.99	1552±35 AD	WA99TLfg373	NM/LA298/20707	o	2.93±0.19	1	TL1;Q;240°C;280-320°C	6.57±0.29	1.72±0.09	38.8	47.3	8.4	5.6	10	12	0
68.100	*1713±27 AD*	WA00TLfg408	NM/LA14904/fs219	ms	1.44±0.12	1	TL1;Q;240°C.290-360°C	5.03±0.20	1.83±0.12	36.3	41.2	16.6	5.9	7	12	24
68.100	1666±27 AD	WA00TLfg409	NM/LA14904/fs237	ms	1.53±0.11	1	TL1;Q;240°C.300-390°C	4.58±0.16	1.63±0.06	31.3	44.2	18.3	6.2	7	12	30
68.102	*1805±34 AD*	WA00TLfg410	NM/LA14904/fs225	ms	0.87±0.15	0.78±0.06	TL1;L;240°C.320-400°C	4.45±0.16	1.53±0.08	28.5	45.6	19.4	6.5	7	12	26
68.103	1683±32 AD	WA00TLfg411	NM/LA14904/f5117	ms	1.26±0.11	0.88±0.04	TL1;L;240°C.250-400°C	3.98±0.20	2.26±0.13	37.6	34.0	21.0	7.4	6	12	25
68.104	1655±28 AD	WA00TLfg412	NM/LA14904/fs231	ms	1.71±0.12	1	TL1;Q;240°C.320-400°C	4.98±0.21	1.98±0.16	36.5	41.6	15.6	6.3	7	12	15
68.105	*1850±15 AD*	WA00TLfg413	NM/LA14904/fs265	ms	1.03±0.09	0.74±0.05	TL1;L;240°C.260-340°C	6.91±0.30	1.71±0.10	37.8	44.1	13.5	4.5	8	12	15
68.106	1619±50 AD	WA00TLfg430	CO/5SM2425/2204	o	1.77±0.20	1	SARA;L;240°C;240-400°C	4.59±0.23	1.75±0.21	27.5	50.8	15.0	6.5	10	12	15
68.107	1654±37 AD	WA00TLfg463	NM/LA16257fs547	os	2.04±0.20	0.82±0.05	TL1;Q;240°C.310-400°C	5.90±0.23	1.71ë0.09	35.8	39.1	19.1	6.0	7	9	18

Notes.

1. Dates in italics are for samples that exhibited anomalous fading and can only be considered minimums. In addition, fading tests were not conducted on a number of sherds, due to insufficient material. These are sherd references: 137, 150, 151, 237a, 238b, 243, 308, 313, 332, 345, 346, 347, 350, 366, 368
2. For the five samples for which TL2 procedure (additive dose extrapolation with supralinearity correction) was followed, the ratio of the second glow intercept to the palaeodose was as follows: #104 (0), #112 (0), #135 (0.16±0.15), #149 (0.09±0.07), #152 (0.05±0.04).
3. For #119, a piece of burned sandstone, OSL was performed as well as TL, and the data reflect weighted averages of both analyses.

Abbreviations

4. List Ref includes the laboratory (WA, or University of Washington), year of analysis, TL or OSL, fine grain (fg) or quartz inclusion (qi), and the laboratory reference number.
5. The column headed by C gives the archaeological context of the sample: pit structure (ps), masonry structure (ms), other kind of structure (os), hearth (h, any feature with carbonized material), rockshelter (rs), rock feature (rf, any small feature constructed with stones, such as mealing bins), midden (m), and other (o, generalized activity areas of habitation sites).
6. P is palaeodose in Gy.
7. m2/m1 is the ratio of slopes of the regeneration and additive dose curves.
8. Procedure includes the basic procedure for determining palaeodose (as referenced in Table 1), fit to the growth curves (L, linear, Q, quadratic, C, cubic), preheat, and plateau region.
9. TotDR is the total dose rate. This is followed by the b-value, and the percent dose rate of alphas, betas, gammas, and cosmic. W refers to moisture contents of sample and environment. Z is the burial depth.