

TASI 10757 Jordan River, Brighton, Tasmania:
Luminescence chronology



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**Report to the Tasmanian Department of Infrastructure,
Energy and Resources**

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Executive summary

Optically stimulated luminescence (OSL) dating was used to constrain the ages of the sediments at TASI 10757, an archaeological open site comprising Aboriginal stone artefacts in alluvial deposits of the Jordan River, near Brighton, Tasmania. Three samples were dated from excavation Trench 2 at the site. An additional two samples were dated from an adjacent quarry to provide maximum bounding ages for alluvial deposition at TASI 10757.

Equivalent radioactive dose (D_e) values for aliquots in OSL JR01 (0.98 m depth) and OSL JR02 (1.90 m depth) from the quarry and OSL JR03 (0.45 m depth) from excavation Trench 2 of TASI 10757 displayed relatively symmetric frequency distributions, suggesting effective resetting of the luminescent traps prior to deposition. Two of the samples from excavation Trench 2 of TASI 10757 (OSL JR04-05) displayed positively skewed frequency distributions, suggesting those aliquots with the highest D_e values had been inadequately reset and were therefore excluded from the age calculations.

The results exhibit internal consistency, with the sequences yielding ages in stratigraphic succession. The dating program shows alluvial deposition at the site occurred during the middle of the last glacial period. At the quarry, medium sands at 1.90 m depth are $59,400 \pm 3600$ years old (OSL JR02) and fine sands at 0.98 m depth are $54,400 \pm 3900$ years old (OSL JR01). Fine to medium sands at excavation Trench 2 of TASI 10757 are $37,500 \pm 3800$ years old (OSL JR05) at 0.65 m depth, $34,000 \pm 2800$ years old (OSL JR04) at 0.55 m depth and $26,600 \pm 2600$ years old (OSL JR03) at 0.45 m depth.

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1 Introduction

Optically stimulated luminescence (OSL) dating was used to constrain the ages of the sediments at TASI 10757, an archaeological open site of Aboriginal stone artefacts in alluvial deposits of the Jordan River, near Brighton, Tasmania. Three samples were dated from excavation Trench 2 at the site. An additional two samples were dated from an adjacent quarry to provide maximum bounding ages for alluvial deposition at TASI 10757.

2 Methodology

OSL is now commonly used for dating sedimentary deposits from a variety of aeolian, fluvial and lacustrine environments (e.g. Stokes, 1999; Olley *et al.*, 2004a). When quartz grains within a sedimentary sequence are buried, they begin to accumulate a trapped-charge population that increases in a measurable and predictable way in response to the ionising radiation dose to which the grains are exposed (Huntley *et al.*, 1985; Aitken, 1998). Exposure to sunlight releases the light-sensitive trapped charge and resets the OSL signal. This process is commonly referred to as 'zeroing' or 'bleaching'. The time lapsed since quartz grains were last exposed to sunlight can be determined by measuring the OSL signal from a sample, determining the equivalent radioactive dose (D_e) that this represents, and estimating the rate of exposure of the grains to ionising radiation since they were buried (the 'dose rate'; D_r) (Aitken, 1998). From these parameters, the burial age of well-bleached grains can be determined (Burial age = D_e / D_r).

The accuracy and precision of OSL ages is partially controlled by the contribution of unbleached grains within a sample (Olley *et al.*, 1999; Murray & Olley, 2002) and this influences which depositional environments will yield the most reliable results. Sedimentary deposits that are likely to have had adequate solar exposure and effective bleaching prior to deposition and burial are preferred targets for OSL dating; most notably aeolian sequences. In other settings such as alluvial and lacustrine deposits, where transport and deposition times may be rapid, the potential for incomplete bleaching is increased. OSL dating of alluvial and lacustrine deposits has recently been aided by the emergence of new methodologies allowing the effective dating of single grains of quartz, which provide information on degree of partial bleaching within a sample (Olley *et al.*, 2004a).

In this study, single grain and small aliquot OSL dating was used to determine the depositional age of five samples from alluvial deposits. Samples were collected by

driving 40 mm diameter opaque stainless steel tubes into cleaned sections.

Sediments were processed under subdued red light, with the 180-212 μm quartz fraction extracted for dating using standard procedures (e.g. Galbraith *et al.*, 1999). A single-aliquot regenerative-dose protocol was used to calculate D_e (Murray & Roberts, 1998; Galbraith *et al.*, 1999; Murray & Wintle, 2000). Single grains were dated from the samples from Trench 2 of TASI 10757 (OSL JR03-05). Samples from the quarry (OSL JR01-02) were dated using small aliquots of around 10-20 grains each.

For the single grain analyses of samples OSL JR03-05, 100 aliquots, each composed of single grains of quartz, were preheated at 240 $^{\circ}\text{C}$ for 10 s and optically stimulated for 2 s at 125 $^{\circ}\text{C}$ by green (532 nm) light from a solid-state laser beam attached to an automated Risø TL-DA-15 apparatus (Markey *et al.*, 1997; Bøtter-Jensen *et al.*, 2000). For the multiple grain analyses of samples OSL JR01-02, 24 aliquots comprising ~10-20 grains each were preheated at 240 $^{\circ}\text{C}$ for 10 s and optically stimulated for 100 s at 125 $^{\circ}\text{C}$ by blue (470 nm) light from a light-emitting diode array on the Risø TL-DA-15 apparatus. Ultraviolet luminescence was detected using photomultiplier tubes with a 7.5 mm Hoya U-340 filter. Samples were then given applied doses using calibrated $^{90}\text{Sr}/^{90}\text{Y}$ beta-sources and re-stimulated to record their regenerative OSL signals. OSL sensitivity changes in the quartz crystals between the natural and regenerative cycles were monitored after each optical stimulation using test-doses of 2 Gy (multiple grains) or 10 Gy (single grains) following a 160 $^{\circ}\text{C}$ cut-heat. Recycling tests using duplicate regenerations of known dose confirmed the reproducibility of the laboratory-induced luminescence signals.

Output from the Risø apparatuses was analysed using Analyst version 3.21 software (Pirtzel, 2006). For multiple grain aliquots, OSL signals were measured for 100 s (250 x 0.4 s channels) and integrated over the first 4.8 s of illumination with the final 20 s converted to the equivalent number of channels over 4.8 s and subtracted as background. Single grains were measured for 2 s (100 x 0.02 s channels) with data integrated from the five channels 5-9. Integrated data from channels 80-90 was converted to the equivalent signal from five channels and used as background. The OSL data were corrected for any sensitivity changes and dose-response curves constructed using five or six regenerative dose points, depending on the magnitude of the D_e of the samples. D_e were obtained from the intercept of the regenerated dose-response curve with the natural luminescence intensity.

K, U and Th concentrations were measured using instrumental neutron activation analysis (INAA) by Becquerel Laboratories, Mississauga, Ontario, Canada, and converted to beta dose rates using the conversion factors of Adamiec & Aitken (1998). A

beta attenuation factor of 0.88 ± 0.03 (Mejdahl, 1979) was assumed. Gamma dose rates were measured in the field using a portable spectrometer and converted to dry values by oven-drying sediment from the sample location. Internal alpha dose rates were also assumed to be 0.03 ± 0.01 Gy/ka based on previous measurements of Australian quartz (e.g. Thorne *et al.*, 1999; Bowler *et al.*, 2003).

Cosmic-ray dose rates were determined from established equations (Prescott & Hutton, 1994), allowing for sample depth, sediment density and site altitude and latitude. Present-day field-moisture contents of the sediments were considered broadly representative of long-term averages and used to correct attenuation of beta and gamma rays by water (Aitken, 1998).

3 Results

The dose rate data, D_e estimates and optical ages for the five OSL samples are presented in Table 1.

The ages are internally consistent, with all samples in stratigraphic succession. All samples contained quartz with luminescence signals dominated by the fast OSL component and displayed acceptable recycling ratios.

The single aliquot D_e distributions are displayed in radial plots (Figures 1-5). These show the distribution of aliquots with their precisions. Statistically concordant aliquots at the 2σ confidence level are within ± 2 units on the y-axis (shaded).

A powerful application of single aliquot optical dating is that D_e estimates obtained from individual small aliquots or grains can be compared to identify possible cases of partial bleaching. D_e frequency distributions can be used to assess the likelihood that aliquots consist only of grains that were well-bleached at deposition (Murray *et al.*, 1995; cf. Wallinga, 2002). Olley *et al.* (1998, 1999, 2004a, b) have shown that the more asymmetric the distribution, the more likely that the aliquots with the highest D_e values have been inadequately reset. In such cases, the lowest D_e estimates usually most closely represent the true burial dose.

D_e values for aliquots in OSL JR01-03 displayed relatively symmetric frequency distributions, suggesting effective resetting of the luminescent traps prior to deposition. Optical ages were thus derived from weighted mean D_e using the central age model of Galbraith *et al.* (1999).

D_e values for aliquots in OSL JR04-05 displayed positively skewed frequency distributions, suggesting those aliquots with the highest D_e values had been inadequately reset. Aliquots with the highest D_e values (greater than 200 Gy) were

therefore excluded from the age calculations (9 % of aliquots for OSL JR04 and 35 % of aliquots for OSL JR05), with the ages derived from weighted mean D_e of the remaining, younger aliquots using the central age model of Galbraith *et al.* (1999).

Table 1. Luminescence age results

Sample name	Depth (m)	Water ^a (%)	Radionuclide concentrations ^b			α radiation ^c (Gy ka ⁻¹)	β radiation ^d (Gy ka ⁻¹)	γ radiation ^e (Gy ka ⁻¹)	Cosmic-ray radiation ^f (Gy ka ⁻¹)	Total dose rate (Gy ka ⁻¹)	Equivalent dose ^g (Gy)	Optical age (ka)
			K (%)	Th (ppm)	U (ppm)							
JR01	0.98	10 ± 2	1.18 ± 0.04	8.99 ± 0.28	1.78 ± 0.06	0.03 ± 0.01	1.11 ± 0.05	0.75 ± 0.06	0.18 ± 0.02	2.08 ± 0.08	113 ± 7	54.4 ± 3.9
JR02	1.90	10 ± 2	0.95 ± 0.03	6.09 ± 0.19	1.13 ± 0.04	0.03 ± 0.01	0.84 ± 0.04	0.66 ± 0.05	0.15 ± 0.02	1.68 ± 0.07	100 ± 5	59.4 ± 3.6
JR03	0.45	5 ± 2	1.11 ± 0.04	14.14 ± 0.43	2.38 ± 0.08	0.03 ± 0.01	1.33 ± 0.06	1.03 ± 0.08	0.19 ± 0.02	2.57 ± 0.10	68 ± 6	26.6 ± 2.6
JR04	0.55	5 ± 2	1.15 ± 0.04	14.29 ± 0.44	2.35 ± 0.08	0.03 ± 0.01	1.35 ± 0.06	1.04 ± 0.08	0.19 ± 0.02	2.61 ± 0.10	89 ± 6	34.0 ± 2.8
JR05	0.65	5 ± 2	1.11 ± 0.04	12.51 ± 0.38	2.15 ± 0.07	0.03 ± 0.01	1.26 ± 0.06	1.04 ± 0.08	0.19 ± 0.02	2.52 ± 0.10	95 ± 9	37.5 ± 3.8

^a estimated time-averaged moisture contents, based on measured field water values (% dry weight)

^b obtained by INAA (Bequerel Laboratories, Mississauga, ON, Canada)

^c assumed internal alpha dose rate

^d derived from INAA radionuclide concentration measurements using the conversion factors of Adameic and Aitken (1998), corrected for attenuation by water and beta attenuation

^e derived from field gamma spectrometry measurements using the conversion factors of Adameic and Aitken (1998), corrected for attenuation by water

^f calculated using the equation of Prescott and Hutton (1994), based on sediment density, depth and site latitude and altitude

^g central age model (Galbraith *et al.* 1999), including a ± 2 % systematic uncertainty associated with calibration of the laboratory beta-source.

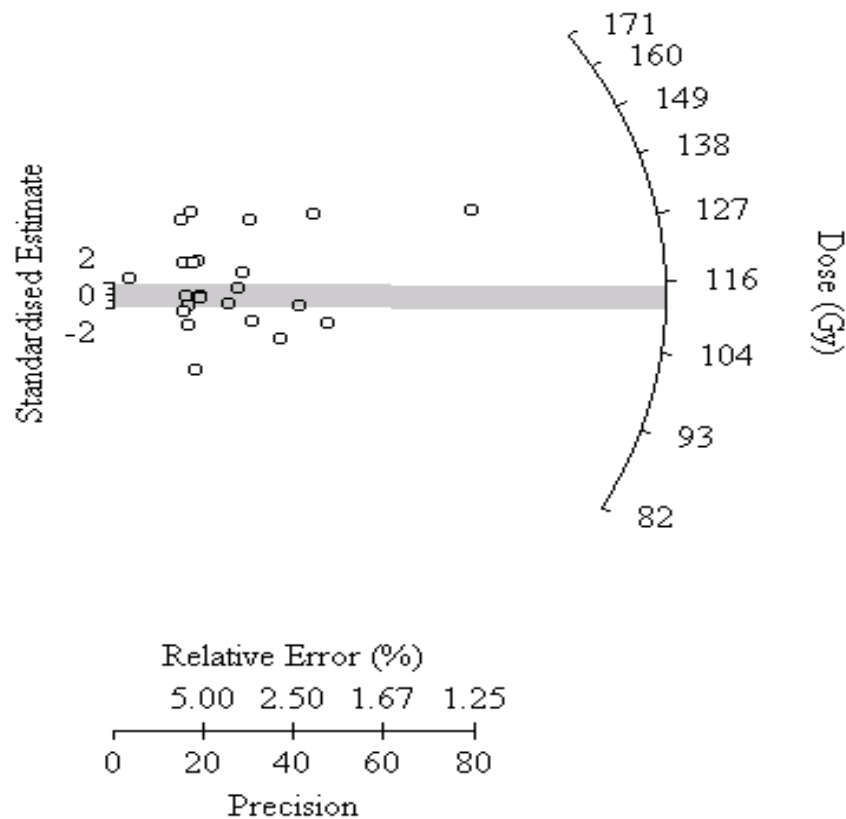


Figure 1. Radial plot of single aliquot D_e distributions for OSL JR01.

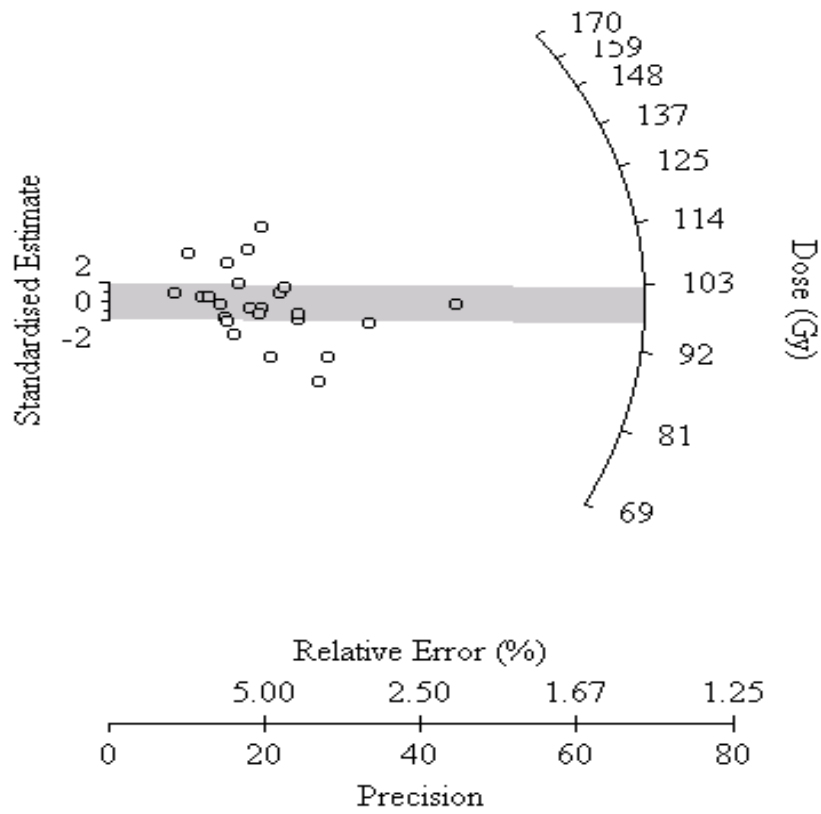


Figure 2. Radial plot of single aliquot D_e distributions for OSL JR02.

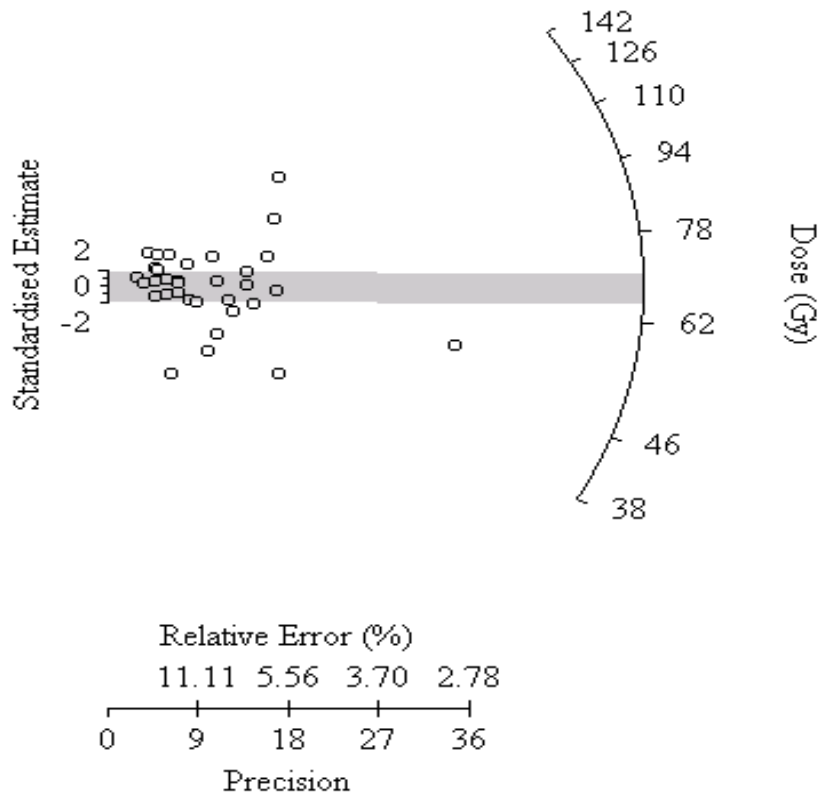


Figure 3. Radial plot of single aliquot D_e distributions for OSL JR03.

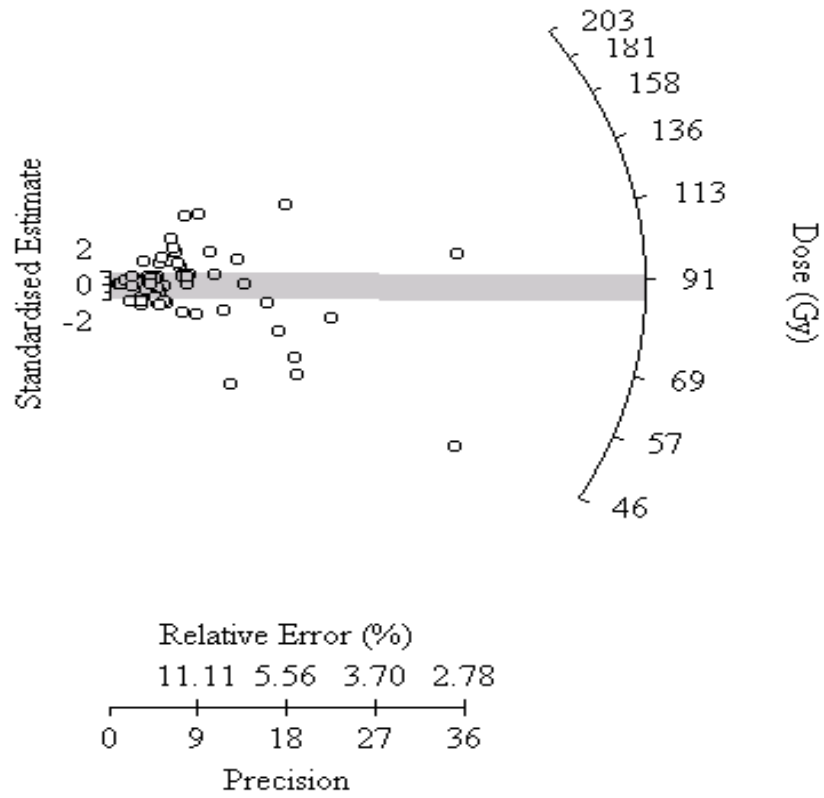


Figure 4. Radial plot of single aliquot D_e distributions for OSL JR04.

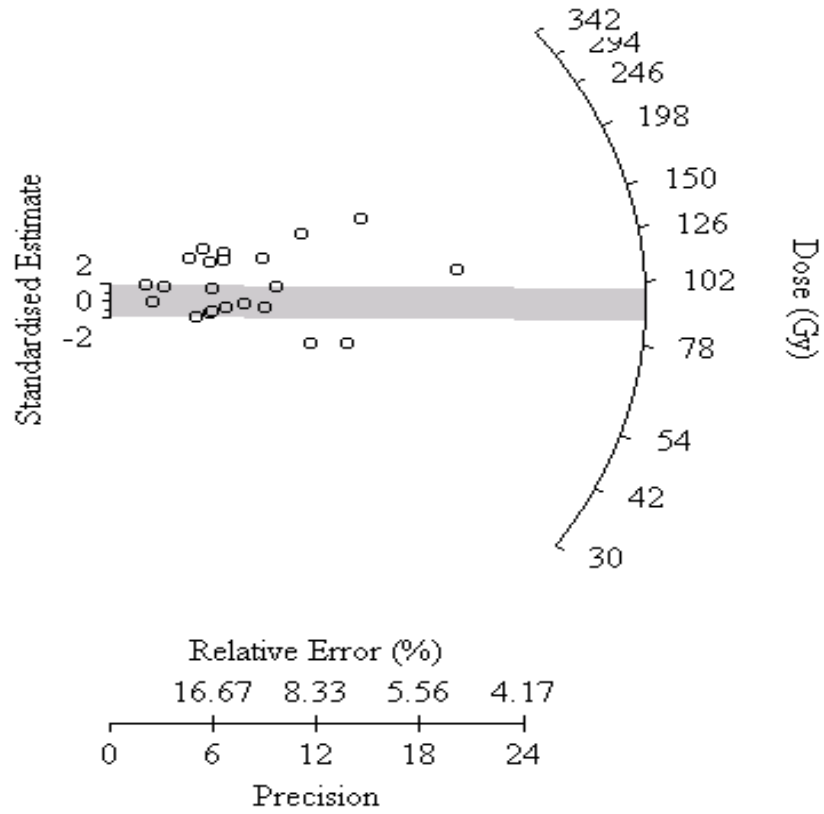


Figure 5. Radial plot of single aliquot D_e distributions for OSL JR05.

4 Discussion and conclusions

The dating program shows alluvial deposition at TASI 10757 occurred during the middle of the last glacial period. At the quarry, medium sands at 1.90 m depth are $59,400 \pm 3600$ years old (OSL JR02) and fine sands at 0.98 m depth are $54,400 \pm 3900$ years old (OSL JR01). Fine to medium sands at excavation Trench 2 of TASI 10757 are $37,500 \pm 3800$ years old (OSL JR05) at 0.65 m depth, $34,000 \pm 2800$ years old (OSL JR04) at 0.55 m depth and $26,600 \pm 2600$ years old (OSL JR03) at 0.45 m depth.

The results exhibit internal consistency, with the sequences yielding ages in stratigraphic succession. Equivalent radioactive dose (D_e) values for aliquots in OSL JR01-03 displayed relatively symmetric frequency distributions, suggesting effective resetting of the luminescent traps prior to deposition. Two of the samples from excavation Trench 2 of TASI 10757 (OSL JR04-05) displayed positively skewed frequency distributions, suggesting those aliquots with the highest D_e values had been inadequately reset and were therefore excluded from the age calculations.

5 References

- Adamic, G. & Aitken, M.J. (1998) Dose-rate conversion factors: update. *Ancient TL* **16**, 37-50.
- Aitken, M.J. (1998) *An introduction to optical dating: the dating of quaternary sediments by the use of photon-stimulated luminescence*. Oxford University Press, Oxford, 267pp.
- Bøtter-Jensen, L., Bulur, E., Duller, G.A.T. & Murray, A.S. (2000) Advances in luminescence instrument systems. *Radiation Measurements* **32**, 523–528.
- Bowler, J.M., Johnston, H., Olley, J.M., Prescott, J.R., Roberts, R.G., Shawcross, W. & Spooner, N.A., (2003) New ages for human occupation and climatic change at Lake Mungo, Australia. *Nature* **421**, 837-840.
- Galbraith, R.F., Roberts, R.G., Laslett, G.M., Yoshida, H. & Olley, J.M. (1999) Optical dating of single and multiple grains of quartz from Jinmium rock shelter, northern Australia: Part I, experimental design and statistical models. *Archaeometry* **41**, 339-364.
- Huntley, D.J., Godfrey-Smith, D.I. & Thewalt, M.L.W. (1985) Optical dating of sediments. *Nature* **313**, 105-107.
- Markey, B.G., Bøtter-Jensen, L. & Duller, G.A.T. (1997) A new flexible system for measuring thermally and optically stimulated luminescence. *Radiation Measurements* **27**, 83–89.
- Mejdahl, V. (1979) Thermoluminescence dating: beta-dose attenuation in quartz grains. *Archaeometry* **21**, 61-72.
- Murray, A.S. & Roberts, R.G. (1998) Measurement of the equivalent dose in quartz using a regenerative-dose single-aliquot protocol. *Radiation Measurements* **29**, 503-515.
- Murray, A.S. & Wintle, A.G. (2000) Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements* **32**, 57-73.
- Murray, A.S. & Olley, J.M. (2002) Precision and accuracy in the optically stimulated luminescence dating of sedimentary quartz: a status review. *Geochronometria* **21**, 1-15.
- Murray, A.S., Olley, J.M. & Caitcheon, G.G. (1995) Measurement of the equivalent doses in quartz from contemporary water-lain sediments using optically stimulated luminescence. *Quaternary Geochronology* **14**, 365-371.

- Olley, J.M., Caitcheon, G.G. & Murray, A.S. (1998) The distribution of apparent dose as determined by optically stimulated luminescence in small aliquots of fluvial quartz: implications for dating young sediments. *Quaternary Geochronology* **17**, 1033-1040.
- Olley, J.M., Pietsch, T. & Roberts, R.G. (2004a) Optical dating of Holocene sediments from a variety of geomorphic settings using single grains of quartz. *Geomorphology* **60**, 337-358.
- Olley, J.M., De Deckker, P., Roberts, R.G., Fifield, L.K., Yoshida, H. & Hancock, G. (2004a) Optical dating of deep-sea sediments using single grains of quartz: a comparison with radiocarbon. *Sedimentary Geology* **169**, 175-189.
- Pirtzel, L. (2006) *Analyst Version 3.21*. Risø National Laboratory, Roskilde, Denmark.
- Prescott, J.R. & Hutton, J.T. (1994) Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. *Radiation Measurements* **23**, 497-500.
- Stokes, S. (1999) Luminescence dating applications in geomorphological research. *Geomorphology* **29**, 153-171.
- Thorne, A., Grün, R., Mortimer, G., Simpson, J.J., McCulloch, M., Taylor, L. & Curnoe, D. (1999) Australia's oldest human remains: age of the Lake Mungo skeleton. *Journal of Human Evolution* **36**, 591-612.
- Wallinga, J. (2002) On the detection of OSL age overestimation using single-aliquot techniques. *Geochronometria* **21**, 17-26.