Rhodes, E.J., 2012. IRSL sediment dating results, Keeler Dunes and related sites, California. Report to Desert Research Institute, November 2012.

IRSL sediment dating results, Keeler Dunes and related sites, California

Introduction

This report provides results of single grain Infra-Red Stimulated Luminescence (IRSL) dating measurements made for sediment samples collected from sites close to Keeler, California. Sampled sites include one beach ridge site and two longitudinal sand dune locations. Measurements were conducted at the site, and samples were collected for subsequent laboratory determinations at UCLA (University of California, Los Angeles). An introduction to OSL (Optically Stimulated Luminescence) dating methods is provided by Rhodes (2011).

Project summary

The aims of this project were to determine the depositional age of sediments at selected locations close to Keeler, California.

For this part of the project, eight sediment samples were prepared, selected from a suite of sixteen collected. IRSL measurements based on K-feldspar grains were conducted, including equivalent dose determinations and detailed fading measurements. All eight samples measured display sensitive IRSL signals, and provide single grain equivalent dose results that allow age estimates to be calculated. The age estimate results appear consistent between the different samples from the same site and with stratigraphic (age order) constraints; this stratigraphic consistency provides an additional degree of confidence in the reliability of the age estimates.

Fading determinations were made for a large contingent of single grains; the most precise determinations come from sample KD12-14 (laboratory code J0289), and results based on these determinations were used to calculate fading corrections for all the samples. The detailed fading determinations for sample KD12-14 are also consistent with other samples from southern California, and indicate relatively low fading values for the IRSL signal measured at 50°C. This fading rate is in contrast to results from a few other sites in southern California that are characterised by significantly higher fading rates. Fading corrections applied to the raw equivalent doses are based on g-values of 0.05 for the IR50 determinations and 0.01 for the PIRIR225 data. The g-value corrects for a logarithmic signal loss, and represents the signal loss per decade (that is for each factor of 10 increase in time; Auclair et al., 2003).

Measurements were made using a version of the newly developed Post-Infra-Red IRSL method of Buylaert et al. (2009), in which signals less prone to fading are also measured. Post-IR IRSL values measured at 225°C are in reasonable agreement with fading-corrected values measured at 50°C, providing support for the results obtained. However, the number of grains that provide signals at 225°C was not great for each of these samples; consequently these 225°C results are of reduced statistical significance, and more emphasis is placed on the results measured at

50°C. Caveats and uncertainties, and guidance in the interpretation of these age estimates, are included below.

IRSL dating sample collection and preparation

Luminescence dating sample locations were identified in advance of the site visit; locations considered likely to provide sediment suitable for dating had been selected, comprising sandy, well-sorted sediments. Sampling locations were named by site number; samples were collected at sites 3, 4, 5, 8 and 9. Eight samples were processed from a suite of sixteen collected from natural exposures in the case of shorelines or delta sediments (sites 3, 4, 9), or by vertical augering for the sand dune locations (sites 5 and 8).

At each sampling position with exposed vertical sections, steel tubes were inserted horizontally. When filled, the tubes were withdrawn, capped and placed in light-tight bags. At these locations, the hole was deepened using a hand auger, and direct measurements of the environmental dose rate made using a calibrated portable NaI microNomad EG&G gamma spectrometer. In the case of the sand dune auger samples, one of two techniques was adopted. Either a split corer head containing a 6" aluminum was mounted and inserted into the auger hole, and hammered into the sediment below, or alternatively, a bucket auger was used, and the sand within the bucket was subsampled using a similar 6" aluminum tube after the auger was raised to the surface. The latter technique was found to be quicker and more efficient. Both of these auger sampling methods run the risk of incorporating grains from higher levels within the dune, including surface layers, as the uncased walls of the auger hole can provide material falling from the walls to the base of the hole. A large diameter rigid plastic pipe was inserted at the top of each auger hole to reduce the risk of collapse or infill from the surface, but the very dry nature of the sand rendered this effect hard to prevent from lower levels. One advantage of the single grain dating approach adopted is that it offers the possibility of detecting and avoiding the malign effects of such sample contamination. For the dune samples, a single NaI gamma spectrometer reading was made in representative sand at site 5.

In the laboratory at UCLA, sample tubes were opened under controlled laboratory lighting conditions. Sediment from both ends of each tube was removed, and not included in the dating sample, as this material had been subject to light exposure during the collection process. At least 4 cm was removed from the upper end of each auger tube, representing material that may have fallen into the auger hole before sampling. Each sample was wet-sieved using disposable nylon mesh screens, and grains of 175-200 µm were selected. These were subsequently treated with dilute HCl to remove carbonate. Grains of density less than 2.58 $g.cm^{-3}$ were separated using a dense solution of lithium metatungstate (LMT), incorporating centrifuge separation and freezing with liquid nitrogen of the denser component. IRSL signals from this material (< 2.58 $g.cm^{-3}$) are considered to be dominated by emissions from feldspar rich in potassium. Individual grains were sprinkled into small holes within a number of anodized aluminum discs, and excess grains brushed off. This mineral fraction was selected for age determination as quartz in Southern Californian locations can display low sensitivity, often making quartz OSL age determination difficult and less precise than when applied elsewhere, whilst K-feldspar typically has a significantly higher sensitivity. Quartz OSL age estimates have also been reported as providing unreliable age determinations in Southern California, possibly as a result of signal contamination by small mineral inclusions with quartz grains, and no quartz fractions were separated for samples from this site.

IRSL measurement

Luminescence measurements were performed using a Risø TL-DA-20D automated reader with a combination of BG3 and BG39 optical filters to provide a luminescence emission window in the blue part of the spectrum. For each sample, 200 single grains were measured using a SAR IRSL protocol similar to that developed by Buylaert et al. (2009), providing both a conventional IRSL measurement at 50°C (IR50) and a “post-IR” IRSL measurement at 225°C (PIRIR225). Details have been modified slightly for single grain application. Sediment dose rate calculations are based on in-situ NaI gamma spectrometer readings.

Table 1 provides sample locations and depths from the present surface, along with field and laboratory codes, and fading-corrected age estimates for IRSL measured at 50°C (IR-50) and post-IR IRSL measurement at 225°C (PIR-IR-225). Ages are presented as years before AD 2012, with associated 1 sigma uncertainties also in years.

The IRSL results suggest a high degree of signal resetting had taken place, as the majority of grains provide a common IR-50 equivalent dose value when an overdispersion (OD) of 15% is incorporated. This additional uncertainty value accounts for between-grain variability caused by effects including slight variations in burial dose rate. For the majority of samples, IRSL dating results are consistent i) for duplicates or stratigraphically close locations (compare the following sample pairs: KD12-01 and KD12-02; KD12-12 and KD12-14; KD12-16 and KD12-17), and ii) between IR-50 and PIRIR-225 determinations (see the same six samples). Of the eight samples measured, two samples do not follow these trends, namely KD12-08 and KD12-10 from site 5. It seems likely that the lowermost sample (KD12-10) from this site was collected from alluvial fan sediments underlying the dune during the augering process. It remains unclear why the upper sample (KD12-08) at this location provides an apparent discrepancy between IR-50 and PIRIR-225 results (300 ± 20 and 1000 ± 150 years respectively), but this probably relates to the small number of grains providing PIRIR signals at 225°C; the corrected IR-50 result of 300 ± 20 years is probably the more reliable estimate for this location.

Table 1.

Field code	Lab code	Site	Sediment type	Depth (m)	IR-50 (years)		1 sigma uncertainty	PIR-IR-225 (years)		1 sigma uncertainty
KD12-01	J0276	Site 4	Shoreline	0.46	3490	±	260	3690	±	260
KD12-02	J0277	Site 4	Shoreline	0.46	3620	±	260	3620	±	270
KD12-08	J0283	Site 5	Dune	0.75	300	±	20	1000	±	150
KD12-10	J0285	Site 5	Dune	2.00	5000	±	210	7870	±	360
KD12-12	J0287	Site 8	Dune	0.87	400	±	30	500	±	150
KD12-14	J0289	Site 8	Dune	2.00	420	±	30	580	±	150
KD12-16	J0291	Site 8	Dune	3.00	710	±	40	600	±	150
KD12-17	J0292	Site 8	Dune	3.73	620	±	30	620	±	150

Summary and conclusions

Analysis of detailed fading data for these samples show lower fading rates (g-values) than at other sites, reducing the magnitude of the age correction applied. The age estimates presented in Table 1 represent the best estimate of depositional age available at this time. The high degree of stratigraphic consistency, and also the apparent agreement between IR-50 and PIRIR-225 IRSL results for six samples, provides an additional degree of confidence in these results. The results for dune site 5 are less clear cut, and probably represent material from an underlying, partially reset alluvial fan deposit (KD12-10), and for the upper sample (KD12-08), the PIRIR-225 result is considered less reliable.

References cited

Auclair, M., Lamothe, M., Huot, S. 2003 Measurement of anomalous fading for feldspar IRSL using SAR. Radiation Measurements 37, 487–492.

Buylaert, J.P., Murray, A.S., Thomsen, K.J., Jain, M. 2009 Testing the potential of an elevated temperature IRSL signal from K-feldspar. Radiation Measurements 44, 560-565.

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Appendix 1 – summary of values used in age calculations

Sample number Lab code K-FELDSPAR	KD12-01 J0276 IR50	KD12-02 J0277 IR50	KD12-08 J0283 IR50	KD12-10 J0285 IR50	KD12-12 J0287 IR50	KD12-14 J0289 IR50	KD12-16 J0291 IR50	KD12-17 J0292 IR50
De (Gy)	12.75	13.20	1.42	23.65	1.92	1.99	3.35	2.88
uncertainty	0.84	0.84	0.10	0.48	0.11	0.11	0.12	0.12
measured	0.80	0.80	0.10	0.10	0.10	0.10	0.10	0.10
0.020	0.255	0.264	0.028	0.473	0.038	0.040	0.067	0.058
Grain size								
Min. grain size (µm)	175	175	175	175	175	175	175	175
Max grain size (µm)	200	200	200	200	200	200	200	200
External gamma-dose (Gy/ka)	1.177	1.177	1.619	1.619	1.619	1.619	1.619	1.619
error	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
INTERNAL K content (% K)	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
error	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
INTERNAL Dose rate	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
error	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
Measured concentrations								
standard fractional error	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
% K	1.749	1.749	2.563	2.563	2.563	2.563	2.563	2.563
error (%K)	0.087	0.087	0.128	0.128	0.128	0.128	0.128	0.128
Th (ppm)	5.747	5.747	7.514	7.514	7.514	7.514	7.514	7.514
error (ppm)	0.287	0.287	0.376	0.376	0.376	0.376	0.376	0.376
U (ppm)	2.119	2.119	2.856	2.856	2.856	2.856	2.856	2.856
error (ppm)	0.106	0.106	0.143	0.143	0.143	0.143	0.143	0.143
Cosmic dose calculations								
Depth (m)	0.460	0.460	0.750	2.000	0.870	2.000	3.000	3.730
error (m)	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Average overburden density (g.cm^3)	1.900	1.900	1.900	1.900	1.900	1.900	1.900	1.900
error (g.cm^3)	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Latitude (deg.), north positive	35	35	35	35	35	35	35	35
Longditude (deg.), east positive	-117	-117	-117	-117	-117	-117	-117	-117
Altitude (m above sea-level))	640	640	640	640	640	640	640	640
Soft Cosmic	0.030	0.030	0.005	0.005	0.005	0.005	0.005	0.005
Cosmic dose rate (Gy/ka)	0.250	0.250	0.216	0.185	0.213	0.185	0.163	0.150
error	0.033	0.033	0.021	0.014	0.020	0.014	0.012	0.011
Moisture content								
Moisture (water / wet sediment)	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
error	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Total dose rate, Gy/ka	**3.65**	**3.65**	**4.76**	**4.73**	**4.76**	**4.73**	**4.71**	**4.69**
error	**0.13**	**0.13**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**
% error	**3.44**	**3.44**	**3.60**	**3.61**	**3.60**	**3.61**	**3.63**	**3.63**
AGE (ka)	**3.49**	**3.61**	**0.30**	**5.00**	**0.40**	**0.42**	**0.71**	**0.61**
error	**0.26**	**0.26**	**0.02**	**0.21**	**0.03**	**0.03**	**0.04**	**0.03**
% error	**7.43**	**7.25**	**8.18**	**4.15**	**6.65**	**6.51**	**5.11**	**5.41**

Sample number Lab code K-FELDSPAR	KD12-01 J0276 IR225	KD12-02 J0277 IR225	KD12-08 J0283 IR225	KD12-10 J0285 IR225	KD12-12 J0287 IR225	KD12-14 J0289 IR225	KD12-16 J0291 IR225	KD12-17 J0292 IR225
De (Gy)	13.48	13.92	4.71	37.21	2.36	2.72	2.80	2.91
uncertainty	0.84	0.85	0.71	1.02	0.70	0.70	0.70	0.70
measured	0.80	0.80	0.70	0.70	0.70	0.70	0.70	0.70
0.020	0.270	0.278	0.094	0.744	0.047	0.054	0.056	0.058
Grain size								
Min. grain size (µm)	175	175	175	175	175	175	175	175
Max grain size (µm)	200	200	200	200	200	200	200	200
External gamma-dose (Gy/ka)	1.177	1.177	1.619	1.619	1.619	1.619	1.619	1.619
error	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
INTERNAL K content (% K)	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
error	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
INTERNAL Dose rate	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
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Measured concentrations								
standard fractional error	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
% K	1.749	1.749	2.563	2.563	2.563	2.563	2.563	2.563
error (%K)	0.087	0.087	0.128	0.128	0.128	0.128	0.128	0.128
Th (ppm)	5.747	5.747	7.514	7.514	7.514	7.514	7.514	7.514
error (ppm)	0.287	0.287	0.376	0.376	0.376	0.376	0.376	0.376
U (ppm)	2.119	2.119	2.856	2.856	2.856	2.856	2.856	2.856
error (ppm)	0.106	0.106	0.143	0.143	0.143	0.143	0.143	0.143
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error (m)	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Average overburden density (g.cm^3)	1.900	1.900	1.900	1.900	1.900	1.900	1.900	1.900
error (g.cm^3)	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Latitude (deg.), north positive	35	35	35	35	35	35	35	35
Longditude (deg.), east positive	-117	-117	-117	-117	-117	-117	-117	-117
Altitude (m above sea-level))	640	640	640	640	640	640	640	640
Soft Cosmic	0.030	0.030	0.005	0.005	0.005	0.005	0.005	0.005
Cosmic dose rate (Gy/ka)	0.250	0.250	0.216	0.185	0.213	0.185	0.163	0.150
error	0.033	0.033	0.021	0.014	0.020	0.014	0.012	0.011
Moisture content								
Moisture (water / wet sediment)	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
error	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Total dose rate, Gy/ka	**3.65**	**3.65**	**4.76**	**4.73**	**4.76**	**4.73**	**4.71**	**4.69**
error	**0.13**	**0.13**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**
% error	**3.44**	**3.44**	**3.60**	**3.61**	**3.60**	**3.61**	**3.63**	**3.63**
AGE (ka)	**3.69**	**3.81**	**0.99**	**7.87**	**0.50**	**0.57**	**0.59**	**0.62**
error	**0.26**	**0.27**	**0.15**	**0.36**	**0.15**	**0.15**	**0.15**	**0.15**
% error	**7.14**	**6.99**	**15.44**	**4.54**	**29.99**	**26.09**	**25.34**	**24.39**