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A method for quickly estimating the equivalent dose in optical dating of K-feldspar

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Introduction

In optical dating, before one can actually determine an age, the sample must go through several processes of washing, drying and grain selection that take considerable time. It sometimes happens that the sample collected has an optical age very much larger than expected. This can happen for example if sampling had yielded material from below a sand dune rather than from the dune itself as intended; it would also occur if the sample desired was obtained, but was not bleached before burial. The purpose of the experiment described below was to determine whether or not a useful preliminary estimation of a sample's equivalent dose and age could be obtained quickly. Raw sand was used for the aliquots, which were measured, given a radiation dose, heated, measured once more, and the equivalent dose estimated. It is found that this method can save grain preparation time and effort if a sample is not what it is thought to be, and may replace the usual pilot experiment to determine the appropriate radiation doses to give prepared grains for optical dating.

Experimental procedure

Twenty samples were chosen from our collection to test the method on a wide range of D_{eq}'s. For each, an equivalent dose and optical age has been obtained using a standard multiple aliquot method on separated K-feldspar grains in a particular size range. For each sample, raw sediment was taken from the original sample to fill three planchets. This means no removal of carbonates, no grain size selection, no magnetic separation, no density separation, no drying. To stick the grains to the planchets, we put a few drops of a thermoplastic polymer (Crystalbond[1]) dissolved in acetone in each planchet, put the raw sediment in and covered the grains with more of this "glue". Then all planchets were heated at 50 °C for an hour so that the acetone would evaporate and the polymer would harden. Except where indicated otherwise, all samples are sand.

1.4 eV (infrared) light from light-emitting diodes (LED's) were used for excitation, and the emission was measured using a Thorn-EMI 9635Q photomultiplier tube and photon-counting electronics. Schott BG-39 and Kopp 5-57 filters were placed in front of the tube to absorb infrared light and to pass the violet emission that is characteristic of K-feldspars.

A first measurement was done on the natural aliquots; the excitation lasted five seconds during which the emission decreased by ~7 %. Then radiation doses of ~60 Gy were given, this dose being chosen to be about twice the largest expected D_{eq}. All aliquots were then heated at 120°C for 16 hours and measured promptly after cooling, using the same conditions as for the first measurement.

Results

For each aliquot, a linear dose response was assumed and the equivalent dose calculated as:

$$D_{eq} = lab.\,radiation\ dose \times \frac{natural\ count}{dose\ count - natural\ count}$$

where the natural count is the sum of the photon counts (minus background counts) from the first measurement, and the dose count is the sum of the photon counts (minus background counts) from the second measurement.

Comparisons of the equivalent doses estimated this way with those obtained earlier using a standard multiple aliquot method are given in Fig.1 and Table 1. We also wanted to see how good an estimate of the age can be obtained by this method, and to this end have calculated an estimated age using an effective dose rate of 2 Gy/ka. Comparison of these ages with the ages obtained previously with the standard method is shown in Table 1.

Discussion

Fig.1 gives evidence of the validity of the raw sand method in estimating equivalent doses. For samples over ~300 years old the estimated values are within a factor of two of the known D_{eq}'s. Differences are expected to be caused by a variety of effects,

[1] Crystalbond 509: Aremco Products Inc., P.O. Box 517, 707-B Executive Blvd., Valley Cottage, N.Y. 10989, U.S.A.

Sample	Equivalent dose (Gy)		Age (ka)	
	multiple aliquot	estimated	multiple aliquot	estimated
SAW03-03	0.00 ± 0.11	0.48	0.000 ± 0.036	0.2
BUCT5-1	0.01 ± 0.08	0.12	0.005 ± 0.030	0.06
SAW03-02	0.06 ± 0.15	0.23	0.021 ± 0.053	0.1
SNO2	0.08 ± 0.01	0.09	0.050 ± 0.007	0.04
SAW01-12	0.30 ± 0.04	0.22	0.14 ± 0.02	0.11
SAW03-04	0.37 ± 0.10	1.19	0.161 ± 0.047	0.6
IC5-02	0.62 ± 0.05	1.37	0.260 ± 0.026	0.68
SAW03-01	0.87 ± 0.10	1.22	0.329 ± 0.046	0.6
CBTS2	2.09 ± 0.13	1.7	1.285 ± 0.095	0.84
BUCT1-1	2.32 ± 0.08	2.4	0.765 ± 0.045	1.2
SNH3	3.15 ± 0.04	4.5	2.08 ± 0.09	2.3
SAW01-06	3.24 ± 0.08	2.4	1.66 ± 0.08	1.2
SN27	7.13 ± 0.14	8.4	5.47 ± 0.24	4.2
IC4-01	10.8 ± 0.8	13.5	4.54 ± 0.42	6.8
SW6-01	10.9 ± 0.3	12.9	4.19 ± 0.20	6.5
LCP5 (peat)	18.8 ± 0.5	18.7	31.2 ± 2.6	37
SAW01-27	25.5 ± 0.7	27.8	15.05 ± 0.97	14
CCL2 (loess)	28.9 ± 2.1	23.4	11 ± 1	12
DY24	36.3 ± 1.2	74	14.7 ± 1.3	37
SAW01-16	in saturation	in saturation		

Table 1.
Comparison of the estimates of equivalent doses and ages using the method described here, with those obtained using a conventional multiple aliquot method. Estimated equivalent doses were determined for three aliquots for each sample and the average taken. Estimated ages were deduced from them assuming the effective equivalent dose rate to be 2 Gy/ka, except for LCP5, a peat, for which 0.5 Gy/ka was assumed.

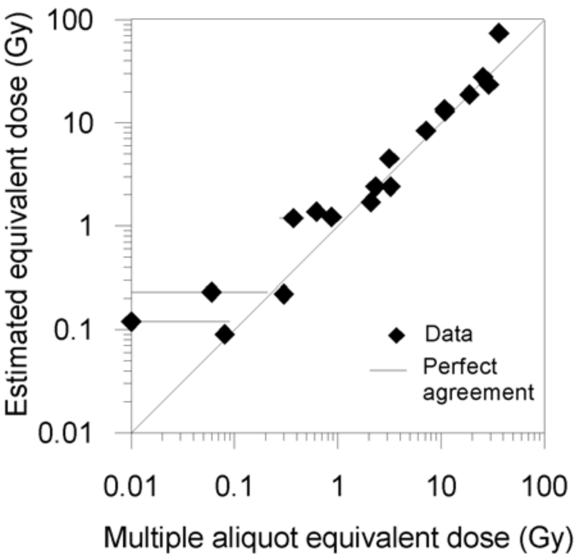

Figure1.
Comparison of estimated and previously determined equivalent doses.

including the variety of grain sizes, the possible presence of minerals other than K-feldspar responding to 1.4 eV excitation, the draining during the first measurement, and some shallow traps being emptied by the heating before the second measurement but not before the first.

In cases where the estimated equivalent dose is similar to that obtained using the standard method, the age obtained using the assumed effective dose rate is generally also reasonable. Hence, if the estimated age is very much higher than expected, it can indicate a lack of exposure to sunlight prior to burial or that the sediment being dated does not correspond to the event for which the dating is intended. The latter could also explain an estimated age much lower than expected. Both situations show the advantages of using this method before starting to prepare a sample for serious dating. In addition, saturation of the traps is very well detected with the method (see SAW01-16); here the dose count is similar to the natural count. Knowing all this, one will not waste time and effort preparing the sediment to find out only later that it cannot be dated.

If one used a shorter, higher-temperature heating and larger dose rate than we used, one could get results within a single day.

The method may be useful for some samples older than those reported on here, but the non-linear dose response will introduce an increasingly large error. It may be possible to modify the equation for D_{eq} to allow for this but this is speculation and requires further experimentation.

Li and Wintle (1994) and Lian and Huntley (1999) earlier sought to extract chronological information from unseparated sediments and appear to have been successful with their different objectives. The experiment of Li and Wintle was similar to ours, but they used a UV exposure instead of the γ-radiation dose, thus they did not obtain D_{eq} estimates. They then measured the response to a dose and suggested a method of obtaining D_{eq} estimates that deals with the non-linear response at high doses.

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Rewiever

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