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Determination of Equivalent Dose by Using the Slow Componenent of IRSL Decay Curves

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ABSTRACT

In this work, the equivalent dose values have been determined using the standard multiple- and single- aliquots process for the geological sample and the infrared stimulated luminescence decay curves were decomposed into fast, medium and slow components using a simple fitting procedure. The Equivalent dose (ED) values were recalculated using these components and the results were compared in between. The ED obtained using the slow components displays comparable results with those obtained by standard methods.

Key Words: Equivalent dose, IRSL, Decay curve, Marmara Sea

1. INTRODUCTION

Infrared stimulated luminescence (IRSL) technique is used to estimate equivalent dose (ED) which can be calculated by comparing the natural IRSL with the IRSL produced by known laboratory doses. Several procedures in which many properties of the OSL mechanisms investigated have been suggested [1-4]. Recently, some studies on ED determination suggest new processes by which more reliable more reliable ED values are obtained more quickly. It has been shown that although the IRSL decay curves have similar characteristic properties, there are important differences in the luminescence behavior. The differences in the luminescence behavior of feldspars or quartz samples have also been investigated. It has been presented that a decay curve is approximately exponential at short times but deviate from exponential at long times [5, 6]. Smith and Rhodes [7] found the emission to be the sum of three signal components, referred to as fast, medium and slow. The fast and medium components dominate in the initial part of the luminescence signal. The slow component refers to a relatively slow depleting portion of the IRSL decay. Bailey [8] showed that the most probable explanation for the OSL signal originates from different traps with different rates of charge loss, of which the slow component is inferred to be deepest, based on laboratory measurements of thermal stability. He has also suggested that the slow component has the effective potential in dating studies. Several studies have indicated that different characteristics of different components may lead to significantly different results in the determination of ED [9-12]. Jain et al. investigated the reduction of the fast component by high temperature infrared stimulation [13].

To determine ED by using the conventional methods, any part (or the entire) of the OSL decay curves can be chosen as the representative luminescence signal. Recently, slow component has been used to obtain the ED values. The slow component refers to a relatively slow depleting portion of the OSL decay. The observation of the slow component requires removal of the other components. This was carried out by Bailey using either optical or by thermal washing (450-500 ^{0}C) [8].

In this work attempts on ED determination were presented using slow components of decay curves from a geological sample. The decay curves from the sample were directly decomposed to obtain fast, medium and slow components. No special treatment was applied to make clear the slow component or the other components. The experimental data was fitted to the following equation, assuming that the decays occurred by the superposition of first-order kinetic decays,

$$I(t)=\sum_{i=1}^{3} I_{0i}\exp(-\lambda_i t)=I_{01}\exp(-\lambda_1 t)+I_{02}\exp(-\lambda_2 t)+I_{03}\exp(-\lambda_3 t) \quad (1)$$

where I_{0i} and λ_i represent the magnitude and the decay constants of each component, respectively. λ_1, λ_2 and λ_3 values were determined from this equation for various beta doses. The fast component has the biggest decay rate whereas the slow component has the

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lowest. The ED was determined using the slow components obtained from this fitting procedure and found to be in agreement with those obtained by using the standard methods.

2. EXPERIMENTAL

All measurements were carried out using the apparatus developed by Spooner et al. in which the basic luminescence reader incorporates an IRSL (880±80 nm) light emitting diode module [14]. All data were collected using IRSL add-on unit for the 9010 automated reader, which uses TEMT 484 IR diodes run at 40mA giving a power of about 30 mW/cm^2 to the sample. Luminescence was detected using a Thorn EMI 9235 QA photomultiplier tube (with a Schott BG-filter). ^{90}Sr-^{90}Y beta-source was used for irradiation. The dose-rate given to sample was 34 mGy/s. The bleaching was carried out by exposing to daylight and controlled by measuring the signals from the sample. All the IRSL signal measurements were made at room temperature.

The sample used in this study was collected from the Sea of Marmara in NW Turkey. A core was extracted from the sample and the inner part of the core was first treated with 10% HCl and then with 40% H_2O_2 to remove carbonate and organic matter. Fine powders of sample were used in the experiments ($< 20\mu m$). The aliquots from sample were prepared by sedimentation in the same weight (~5-6 mg). They were settled onto 1cm diameter Al discs using paraffin oil.

3. RESULTS AND DISCUSSIONS

3.1. ED Determination Using Multiple-Aliquots

Multiple aliquots additive dose measurements were made by the standard procedure with dose normalization. In order to determine the ED seven sets of aliquots (four aliquots for each set) were prepared and exposed to 0, 2, 4, 8, 16, 24 and 32 Gy beta doses at room temperature. Each aliquot was preheated at 200 ^{0}C for 5 minutes. The aliquots were illuminated for 0.1s to be normalized. The IRSL signals were measured for 300s. Decay curves obtained from multiple aliquot additive dose process have been presented in Figure 1.

3.2. ED Determination Using Decomposed Decay Curves

The experimental decay curve data based on multiple-aliquot procedure was also used to determine the fast, medium and slow components of the decay-curves corresponding to each dose. These decay curves were decomposed by a very simple procedure: The intensities and the three decay constants were obtained by fitting experimental data to the Equation 1. The fitting data was given in Table 1. It can be seen that the decay-rates of slow components increase with dose and are slower than other components. The magnitude of the slow component signal grows with dose. For the sample used in this study the slow component contribution to the total IRSL signal has significantly importance. IRSL growth curve was drawn and the ED was determined by extrapolate (Figure 2(a)) and was found as 9.07 Gy. The IRSL intensities of the slow components were plotted versus to beta-doses. The ED was determined by extrapolation and was found as 9.36 Gy (Figure 2(b)).

It is seen that the ED value found using slow components is comparable with that obtained using the standard method. Consequently, ED estimated from the slow component has been shown to be reliable enough. It may indeed be possible to use this method for obtaining the ED estimated from the slow component.

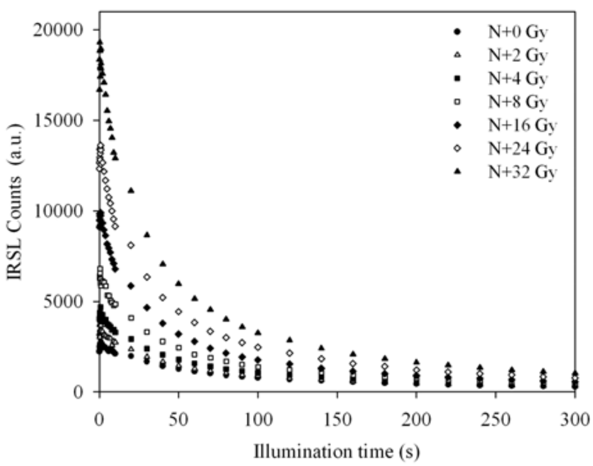

Figure 1. IRSL decay curves from Marmara sample.

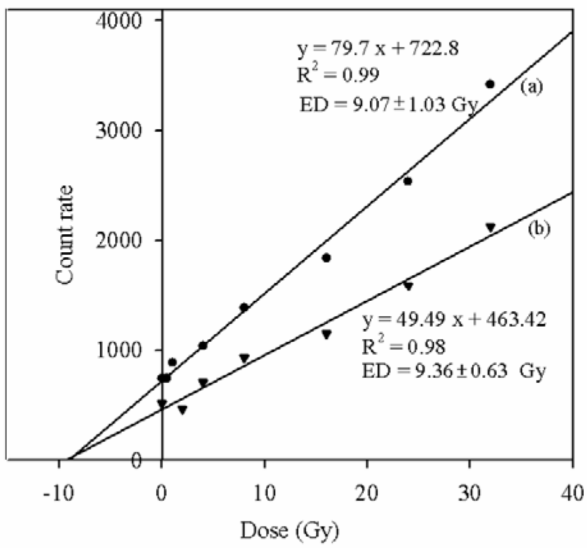

Figure 2. The growth curves: (a) the experimental (b) the slow components using multiple- aliquot additive-dose procedure.

Table 1. The fitting data for Marmara sample*.

Dose (Gy)	Multiple-aliquot Method						Single-aliquot Method					
	Fast		Medium		Slow		Fast		Medium		Slow	
	I_{01}	λ_1	I_{02}	λ_2	I_{03}	λ_3	I_{01}	λ_1	I_{02}	λ_2	I_{03}	λ_3
0	1078.91	0.023	590.54	0.023	908.84	0.0039	315.27	2.676	298.99	0.056	64.60	0.0053
2	1954.30	0.032	676.63	0.010	757.25	0.0033	25.37	0.276	39.763	0.029	12.182	0.0016
4	370.93	0.121	2634.80	0.025	1272.78	0.0041	53.37	0.608	87.547	0.040	20.193	0.0027
8	739.67	0.196	3985.24	0.027	1719.04	0.0043	53.61	1.175	133.195	0.041	39.321	0.0047
16	1592.70	0.127	5993.11	0.028	2178.99	0.0045	-	-	-	-	-	-
24	2422.26	0.124	7875.75	0.027	3023.36	0.0046	57.83	1.01	291.30	0.054	110.75	0.0070
32	3205.19	0.130	11372.5	0.028	4087.22	0.0047	-	-	-	-	-	-

*The fitting procedure was applied to obtain the slow component. The experimental data was fitted to the Equation-1.

3.3. ED Determination Using the Single-Aliquot

In order to check the validity of ED estimation using the slow component and to cope with the inter-aliquot normalization, a SAR (Single Aliquot Regeneration) protocol was used.

An aliquot from Marmara sample was prepared and bleached exposing to daylight for a long time. Background was measured and controlled if it is zeroed. This aliquot was given 14 Gy beta doses, left for 24 hours and heated 5 minutes at 200 ^{0}C. At first the IRSL intensity, L(N), was measured and then 2, 4, 8 and 24 Gy beta doses were given to the aliquot. The aliquot is taken through a measurement cycle of: (i) laboratory added beta-dose; (ii) preheated; (iii) IRSL measurements for 0.1s to normalize; (iv) IRSL measurements for 300 s; (v) bleached exposing to daylight for a long time. The IRSL growth curve from sample was shown in Fig. 3(a). The ED value was found as 15.09 Gy by interpolation. That is ED was found big in magnitude compared to the test dose given to sample.

The experimental data obtained were fitted to Equation-1 and the fast, medium and slow components were determined (Table 1). The ED value from slow components was found as 15.54 Gy (Figure 3(b)).

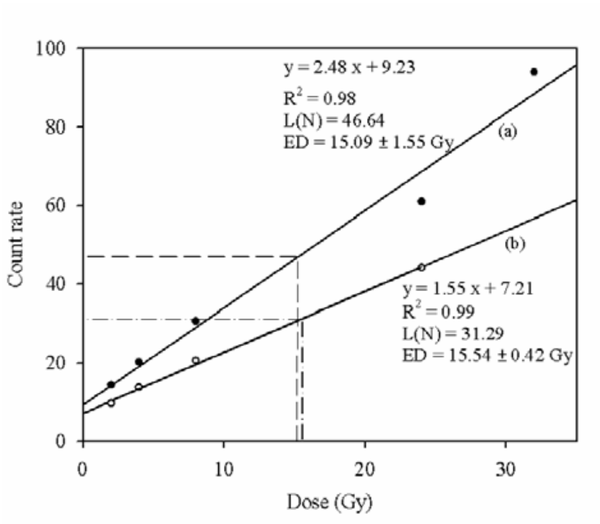

Figure 3. (a) The ED from the experimental growth curve using single-aliquot procedure (b) The ED from the slow components growth curve achieved using single-aliquot procedure.

The decay-constants describing the slower exponential decay were not the same for all doses. They increase with dose given to aliquots. The ED values found using slow components show good agreement with those obtained by simulation. Equivalent doses obtained using the slow components have been in agreement with those obtained by standard methods. It can be seen from Table 1 that the slow components are small in decay constants compared to the fast or medium components of IRSL decay of the feldspars.

4. CONCLUSIONS

It is seen that IRSL decay curve is composed of many exponential components from the simple decomposed analysis used in this work. ED values obtained using slow components of decay curves are founded to be acceptable.

It has been shown that the direct measurement of slow components is possible using a simple deconvolution procedure and the slow component has an important potential for obtaining reliable luminescence dates. Existing conventional methods for ED determination can be verified for the slow components and applied to a variety of sedimentary samples.

In conclusion, we can be used for the precise and accurate estimation of dose thereof. The slow component obtained using a simple fitting procedure.

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