Sensitivity changes of luminescence signals from colluvial sediments after different bleaching procedures

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In a luminescence study of colluvial sediment samples we compared the Equivalent Doses (EDs) obtained by infrared stimulated luminescence (IRSL) and by thermoluminescence (TL) on the identical sample discs. For the youngest sample the IRSL ED was considerably smaller than the ED obtained by TL, thus demonstrating the advantage of this methodology. For the older samples there was a similar overestimation (about 60 Gy) of the ED by TL.
During this study the sensitivity of the IRSL signal was observed after bleaching with a solar simulator and with infrared radiation. The experiments suggested that the sensitivity change is related to the degree of sunlight exposure prior to deposition.

Introduction

In optical dating methods the stimulated luminescence signals are bleached quickly by sunlight (Huntley et al., 1985). It has been suggested that these methods can be used to date materials which have not received prolonged sunlight exposure prior to deposition. For such materials optical dating methods might be expected to have a considerable advantage over TL methods where the residual signal must be considered. In this study we set out to demonstrate this advantage by looking at colluvial deposits from Natal, South Africa (Botha et al. 1990). These sheet wash deposits lie on a low slope and transport distances from source are of the order of 1 km. Previous TL results indicate zeroing problems (Wintle et al. 1992).

Considerable thought has been given to the possibility of TL sensitivity changes induced in the laboratory by artificial light sources and experiments have been carried out using such light sources and sunlight (Wintle 1985). A sensitivity increase has also been reported for the optically stimulated luminescence (OSL) signal from quartz when measured with an argon ion laser (Rhodes, 1990; Smith et al., 1990). Such sensitivity changes would result in incorrect EDs being obtained when using the regeneration method for TL or OSL.

In this paper we examine the implications of sensitivity changes resulting from different illumination histories. The results of IRSL measurements on colluvial deposits after different laboratory light exposures are used to draw conclusions about the effects of the natural light exposure on subsequent ED determinations.

Samples and experimental details

Four colluvial samples (AF-1, AF-2, AF-3 and AF-4) were collected from the St.Paul section at Nqutu, Kwa Zulu, South Africa. Fine grains 4-11 μm were deposited on Al discs using routine preparation methods and were split into four groups for ED determination by additive dose and regeneration methods. Different bleaching treatments were applied to three of the groups prior to using the regeneration method to obtain the ED (a) infrared bleaching for 1600 seconds by the Risø IR/TL system (Bøtter-Jensen et al. 1991). The infrared power at the disc is about 40 mW cm^{-2}. (b) bleaching for 1600 seconds by a Honle SOL2 solar simulator. (c) bleaching for 15 hours by the Honle SOL2. After each bleaching treatment, the IRSL had been reduced to a negligible level, close to the background level measured for a blank disc.

Irradiation was performed with a Daybreak irradiator. To remove the unstable component in the IRSL signal, preheating for 16 hours at 140 °C was performed for all discs and there was at least 24 hours delay after irradiation and after preheating. The IRSL measurements were carried out using an infrared LED array mounted above a Daybreak TL oven. The LEDs were TEMT 484 and the power on the sample disc was about 20 mW cm^{-2} for a current of 20 mA. The IR wavelength (880 ± 80 nm) used for stimulation was the same as that used for the IR bleaching in the Risø IR/TL system. The only optical filter in front of the EMI 9635QB photo-multiplier tube was a 2 mm thick Schott BG 39. The data was taken with an Ortec ACE-MCS card. An integrated photon count for 0.1 seconds (within a 0.12 second exposure) was used, which gives a negligible reduction of the TL signal after each measurement. Subsequent TL measurements were carried out in the Riso reader with two optical filters, one Corning 7-59 and one HA3, in front of the EMI 9635QB photomultiplier tube. The heating rate was 5 °C s^{-1} up to 450 °C.

Growth curves were constructed for both regeneration and additive dose methods. Because the IRSL response was not linear for the three older samples, an exponential curve fitting programme developed for TL growth curves (Smith, 1983) was used.

Results

Typical IRSL growth curves obtained after the different bleaching procedures are shown in fig ure 1a. Each data point represents the mean of 4 measurements. The initial slope (X_o) of the growth curve represents the sensitivity of IRSL after bleaching, and was calculated with the parameters from the fitting curves. For

$$IRSL = k - a\exp(-bD)$$

D is the dose. k, a and b are the fitting parameters.

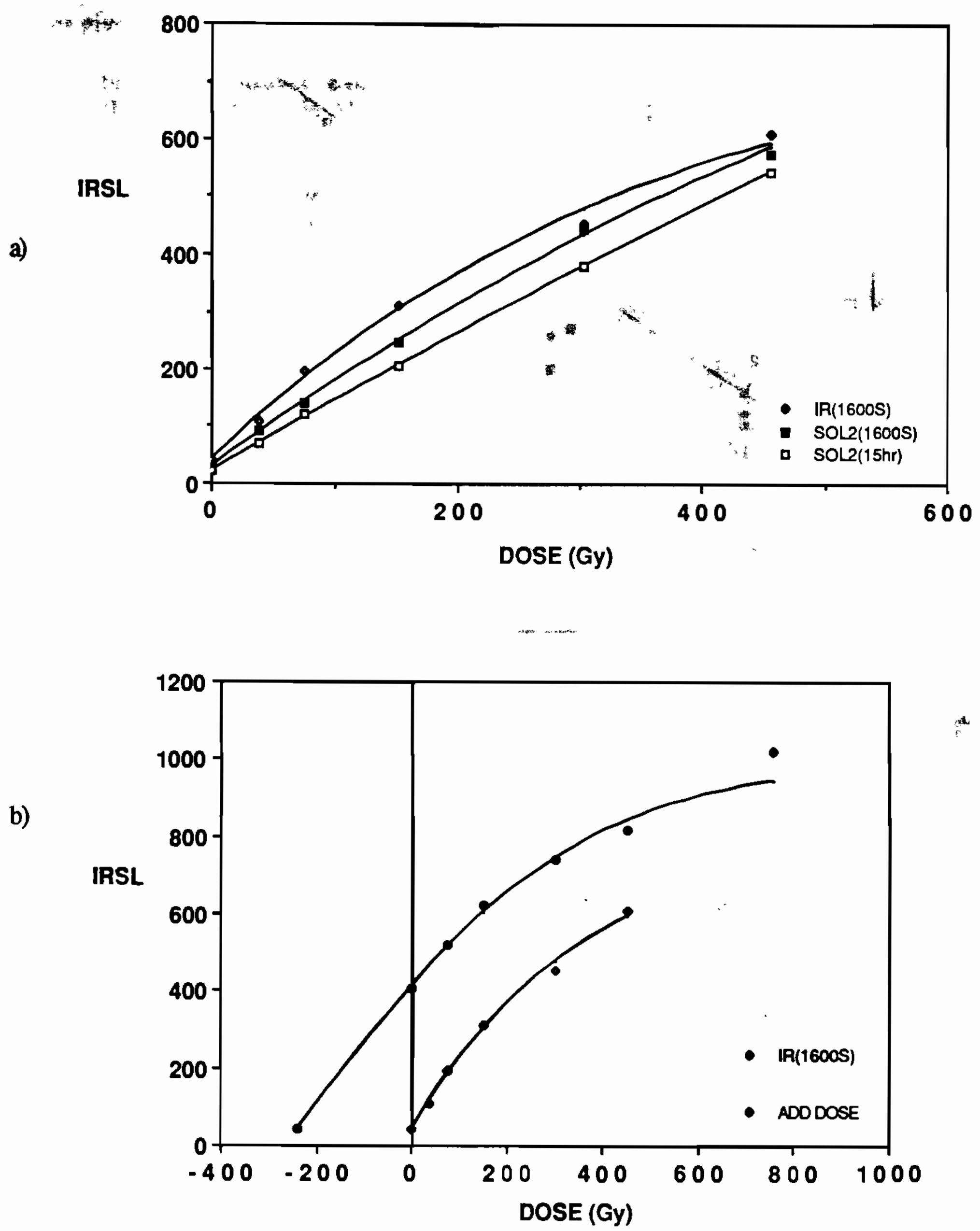

Figure 1. Growth curves for sample AF-1. a) Regeneration after exposure to IR and SOL2. b) additive dose and regeneration after IR bleaching.

The initial slopes were given by

$$X_o = ab\ \exp(-bED) \text{ and } X_o = ab\ (ED{=}0)$$

for the additive dose method and the regeneration method respectively. The results are summarised in fig ure 2a in which the sensitivity for the additive dose method is plotted against the sensitivity after bleaching for the three different treatments.

Discussion

The sensitivity of the IRSL signal for the 3 oldest samples decreases with bleaching time when using the SOL2 solar simulator. A short bleach (1600 s) with IR gives a higher sensitivity than for either SOL2 bleach (figs. 1a and 2a). Significantly different EDs for the regeneration method were thus obtained using these bleaching procedures (table 1 and fig. 2b). In each case the IRSL was bleached to a negligible level before regeneration, and hence the ED differences cannot be explained by the presence of different residual levels.

A comparison of the regenerated IRSL ED values with those given by the additive dose method for the remaining group of discs suggests that only the ED determined after IR bleaching is apparently similar to the additive dose ED for all four samples (fig. 2b; table 1).

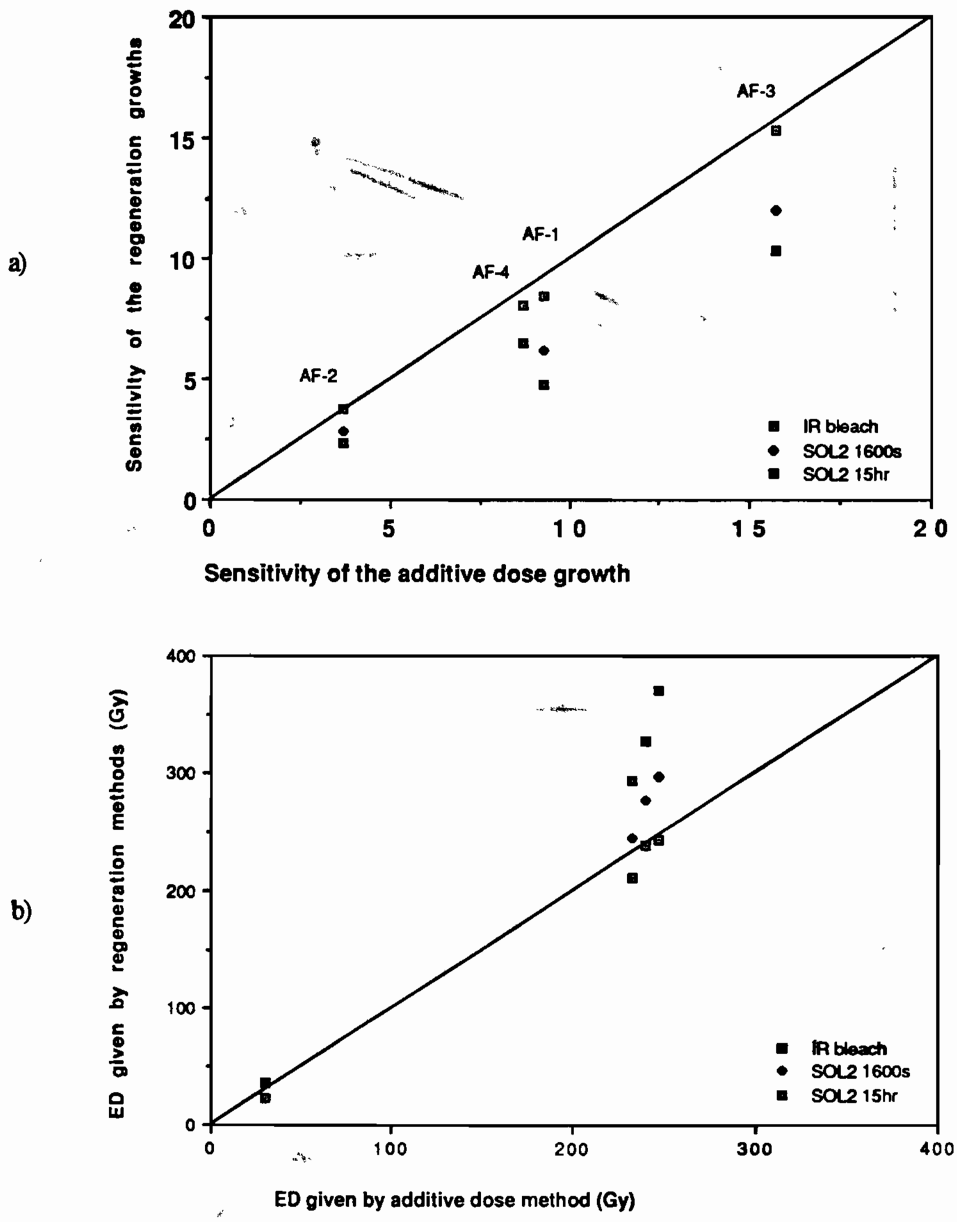

Figure 2. a) Sensitivity of initial IRSL signal measured after bleaching versus the initial sensitivity as obtained by extrapolation for the additive growth data sets. b) IRSL EDs obtained by the regeneration method using different bleachings versus that obtained by the additive dose method for 4 colluvial sediments. The line has a slope of 1.

Table 1. Equivalent dose given by IRSL and TL methods

		samples			
method		AF-4	AF-3	AF-2	AF-1
ADD.Dose	IRSL ED	30 ± 1	233 ± 10	248 ± 21	240 ± 22
	TL ED	90 ± 3	264 ± 15	319 ±14	424 ± 53
Regen. (IR bleach)	IRSL ED	23 ± 3	212 ± 6	243 ± 23	238 ± 23
Regen. (SOL2 1600s)	IRSL ED	-	245 ± 14	297 ± 25	277 ± 23
	TL ED	-	218 ± 3	291 ± 36	295 ± 30
Regen. (SOL2 1600s)	IRSL ED	35 ± 4	293 ± 11	371 ± 32	328 ± 23
	TL ED	104 ± 1	342 ± 20	453 ± 53	451 ± 42

Note. TL residual after 15 hours SOL2 bleaching was used in the ED calculation of the additive dose method.

The ED values given by routine TL measurement were higher than those given by any of the IRSL measurements (table 1). This difference is most clearly demonstrated for the youngest sample AF-4, for which the TL ED was 3 times larger than the IRSL ED. The age derived from the IRSL additive dose ED (5.2 ± 0.3 ka) still gives an overestimate when compared with the ^{14}C date (1.5 ka) from an underlying soil horizon. In spite of this discrepancy the IRSL method is more appropriate for these colluvial samples than TL.

Previous studies on aeolian sediments suggest that the sensitivity of TL signals (Wintle 1985; Rendell and Townsend, 1988) and OSL signals (Smith et al., 1990) changes after laboratory bleaching, with the sensitivity increase being negligible for young samples but significant for old samples (Zhou and Wintle, 1989). These findings contrast with those observed in this study since the IRSL sensitivity decreased rather than increased after bleaching with the SOL2. Not only was this decrease in sensitivity found in older samples, but also in the young sample AF-4. The general difference between aeolian and colluvial sediments is the degree of sunlight exposure prior to deposition. Given the results of the above bleaching experiments, it is possible that the nature of the exposure before deposition could alter the post-depositional IRSL sensitivity of the sample.

Conclusions

The choice of bleaching time and wavelengths to reduce the IRSL signal to a negligible level affects the subsequent response to laboratory dose. This would lead to significantly different EDs being obtained. Comparison of the additive dose ED and EDs obtained by regeneration, suggests that IR bleaching should be used for methods using the regeneration concept, including a single disc approach. That laboratory light exposures can affect IRSL sensitivity suggests that the extent of light exposure prior to incorporation in a sediment deposit will have an effect on subsequent ED determinations. This is confirmed by measurements which show that the decrease in sensitivity of the IRSL signal after SOL2 bleaching found for colluvial samples is not found for loess (Li and Wintle, in preparation).

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