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Use of UV-regenerated IRSL for normalization

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Introduction

In a study of IRSL signals from compressed loess pellets, Li and Wintle (1994) found that there was a considerable difference in the natural IRSL output from pellets of a similar age. It was also found that pellets from a palaeosol gave a lower natural signal than those from loess above it. It is therefore necessary to normalize the signal to allow for individual pellet sensitivity. Different normalization procedures for sample discs have been introduced in luminescence dating techniques (Aitken, 1985; Rhodes, 1990). These involve measurement of the luminescence signals after alpha, beta, or gamma irradiation, but such procedures are not suitable for pellets and a new normalization method has to be introduced.

Exposure of feldspar grains to short wavelength radiation (<300 nm) shows that the IRSL signal is increased for a sample previously bleached by sunlight (Bailiff and Poolton, 1991; Li, 1992). Here we discuss the use of the ultraviolet (UV) regenerated signal for normalization of the IRSL signal from pellets.

Experimental

The equipment used in IRSL measurement was a modified Daybreak manual TL reader (Duller et al., 1992; Li and Wintle, 1992). IR stimulation was provided by a diode array. An optical filter of 2 mm thick Schott BG39 was placed in front of the EMI 9635QB photomultiplier tube used to detect the luminescence emitted from the sample. The IRSL signals were measured with 1 second IR exposure.

The UV radiation source was a mineral lamp (UVP Inc., U.S.A.). The output wavelength peaked at 254 nm. The distance between the UV lamp and the pellets was 10 cm. To minimize the UV power differences, samples were placed within a relatively small area (5x5 cm) beneath the lamp. Under these conditions, the UV-regenerated IRSL signal increased to a maximum level after 1 h UV exposure, and this time was chosen for subsequent experiments.

Pellets were made by compressing with a modified car jack. Each pellet was cylindrical, 10 mm in diameter and weighted about 0.5 g. The height of each pellet was around 6 mm. The pellets were from mixtures of loess with either quartz or carbonate. After the natural IRSL signals had been measured, the pellets were then exposed to sunlight for 6 h to completely remove the natural signal, checked by measuring the IRSL after bleaching. After exposure to UV for 1 h the samples were stored for 16 h and the UV regenerated signal was then measured at room temperature.

UV normalization

The UV normalization was tested by normalizing pellets which contained known proportions of IR sensitive and insensitive materials. Since no IRSL signal has been found in calcite and most quartz (Spooner and Questiaux, 1989; Short and Huntley, 1992), but a signal is found in most feldspar minerals, the IRSL signal will decrease when IRSL insensitive material, such as quartz, is added to a sample with a fixed concentration of feldspar. A 70 ka old Chinese loess was chosen as a homogenous sample containing about 10% feldspar as the IR sensitive material. Finely ground quartz and carbonate from a lake sediment were chosen as the two diluting materials. No IRSL signals were detected from either after a 100 Gy dose. For each material two sets of pellets were made from well-homogenized mixtures with the loess content varying

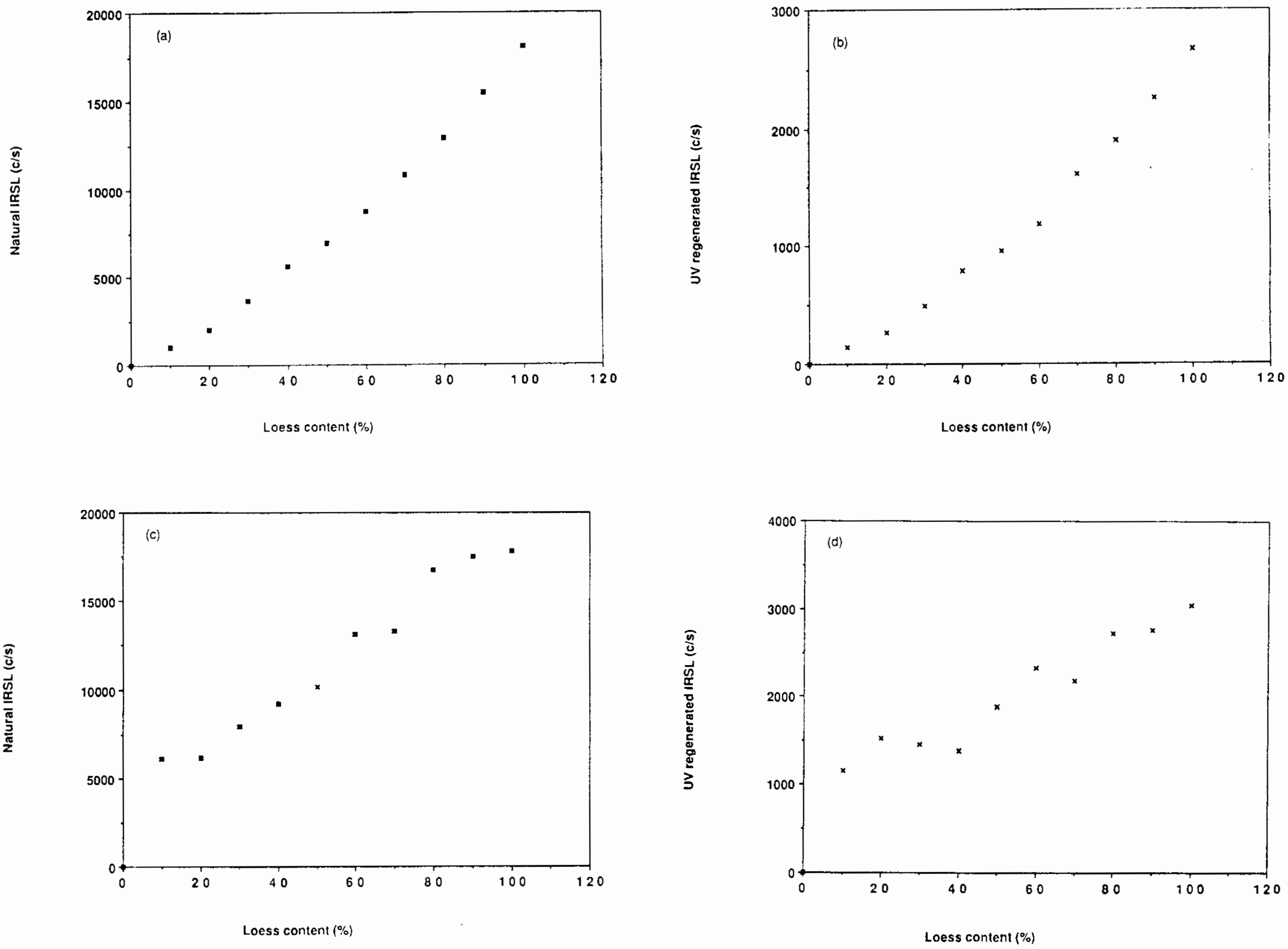

Figure 1.
IRSL signal of pellets of loess mixed with carbonate or quartz. (a) natural signal of loess mixed with carbonate, (b) UV-regenerated signal after sunlight bleaching, the pellets were the same as (a), (c) natural signal of loess mixed with quartz, (d) UV-regenerated signal after sunlight bleaching , the pellets were the same as (c).

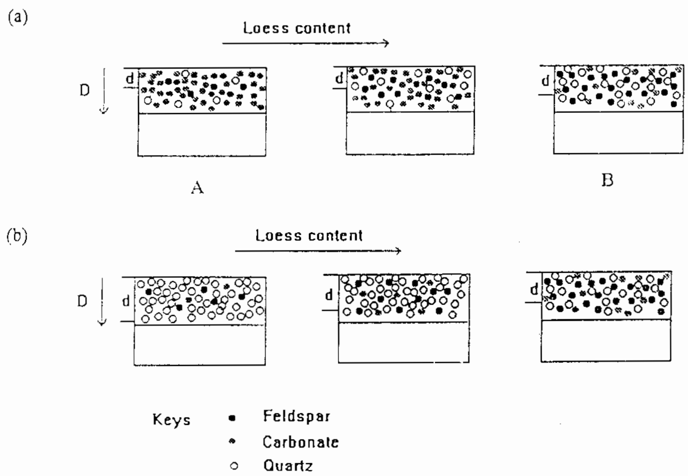

Figure 2.
Schematic diagram for regeneration of the IRSL signal from pellets. (a) loess mixed with carbonate, (b) loess mixed with quartz. Feldspars give rise to the IRSL signal; carbonate can be treated as a mineral which absorbs the IRSL; quartz passes the IRSL signal. D is penetration depth of IR. d is equivalent optical depth for stimulated luminescence.

Table 1. Ratio of normalized IRSL signal from pellets relative to that from 100% loess.

	Ratio	
% loess	Mixture of loess & carbonate	Mixture of loess & quartz*
10	1.07	0.90
20	1.13	0.69
30	1.11	0.93
40	1.06	1.13
50	1.08	0.92
60	1.09	0.96
70	0.99	1.04
80	1.01	1.05
90	1.01	1.08
100	1.00	1.00

N.B. Pellets containing 0, 10 and 20% of loess in the mixture of loess and quartz were not as robust as other pellets and grains were lost during the experiment.

from 0 to 100% in 10% steps. The pellets were sufficiently robust to be handled, except those three pellets which had the highest quartz content.

For both sets of pellets, the natural signals increased monotonically with loess content, though not linearly (Figs 1a & 1c). The UV-regenerated signals also increased with loess content giving a similar pattern as for the natural signals (Figs 1b & 1d). A clear difference can be seen between the response when diluting with quartz and with carbonate. The UV-regenerated signal was used to correct for the response of different loess contents and the results for duplicate pellets are given in Table 1. Values close to unity were obtained suggesting that normalization of the natural IRSL signal can be achieved using this approach.

Effective depth and IRSL

The different responses that occur with carbonate or quartz dilution (shown in Fig. 1) may be explained by invoking an effective depth involved in the production of the natural and UV-regenerated IRSL signals. This is shown schematically in Figure 2. For high carbonate concentrations (A) the IRSL signal from the feldspar grains at depth D (the maximum depth of IR penetration) would be absorbed by the carbonate before it could get through to the surface and be detected. The effective depth d is relatively shallow in this case, with only a few feldspar grains near the surface giving rise to the signal. As the loess concentration was increased (B), the quartz concentration also increased since the loess contains a high percentage of quartz. If quartz is transparent to IRSL, then more IRSL can pass through the quartz grain and thus get through to the surface. The effective depth d is therefore greater. Thus increasing the loess content not only increases the amount of IR sensitive material (feldspars), but also increases the effective depth d of observation of IRSL. Hence, a monotonic but non-linear increase of the IRSL signal would be expected with the increase of loess content, as found in Figures 1a and 1b.

For dilution with quartz, the higher quartz concentration allows most of the IRSL to get through to the surface and results in a greater effective depth d. Although high quartz means there is less feldspar in the pellet, the increased sampling depth makes the IRSL signal decrease more slowly with decreasing loess content, as observed in Figs 1c and 1d. Similarly, in the UV regenerated IRSL signal, the effective depth can also be affected by UV exposure if the penetration depth of the UV is less for carbonate than for quartz. As can be seen in Table 1, a marginal difference in the ratio between pellets containing lowest loess contents is found between both mixtures. This indicates the relative deeper penetration depth of UV in quartz than in carbonate resulting in a relatively large UV regenerated IRSL signal for higher quartz content. However, this has an insignificant effect on the normalization results as close to unity results were obtained in both mixtures.

The UV normalization method has been used satisfactorily in Aberystwyth for several years for pellets and has the potential to be used for grain discs. As has been shown in this study, the UV-regenerated IRSL is related to the feldspar concentration in the sample. The changes in feldspar concentration resulted from weathering and diluting will be reflected in the UV-regenerated signal and therefore further sedimentary information can be provided by the signal (Li, 1992; Li and Wintle, 1994). It is possible that the implications and interpretation of the UV-regenerated signal are more important than just as a normalization method.

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