Selective bleach: an improved partial bleach technique for finding equivalent doses for TL dating of quartz sediments

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Improvements are suggested to the partial bleach method of finding equivalent doses for thermoluminescence dating of sedimentary quartz. They are based on the fact that the 325°C peak in the glow-curve can be completely removed by bleaching with light of relatively long wavelength, that it can be preferentially detected by the use of an optical filter transmitting at 380 nm, and by reduction of the glow-curve heating rate. Attention is drawn to a method of reducing extrapolation errors in finding the equivalent dose from dose growth-curves.

Introduction

The thermoluminescence (TL) dating of sediments is based on the assumption that the TL clock was reset by exposure to sunlight during the time that the sediment was being laid down. Doubts are likely to exist in the dating of sediments because the samples being dated may not have been exposed to sunlight for 'long enough' to reset the clock.

This has been recognised from the beginning (Wintle and Huntley, 1982; Huntley, 1985). They argued that since you do not know how much the sample has been bleached, then you should assume the worst and base your dating on a component in the TL that bleaches easily, assuming that there is one. They introduced the R-Γ Partial Bleach method (R-ß if the radiation is from a beta source). The essential elements are shown in figure 1 which is adapted from Wintle and Huntley (*op cit*).

A range of doses is added to the natural samples being dated. Half of these are bleached by direct or artificial sunlight for a 'short' time, which is long enough to remove any rapidly-bleached TL component but not long enough to remove any significant amount of slowly-bleached TL. This bleaching may be with or without optical filters, depending on the circumstances. The samples are glowed out and the data are used to define a (natural+dose) growth curve and a (natural+dose+bleach) growth curve. The two curves are extrapolated to intersect at a point that defines the Equivalent Dose, D_{eq}.

Optical Improvements

Franklin and Hornyak (1990) and Prescott and Fox (1990) have pointed out that, for quartz, there is an easily-identifiable, rapidly-bleached TL component, viz, the 325°C peak which emits at 380 nm. It is possible to bleach this component completely out selectively, without affecting other glow-curve peaks, with a short exposure to light of wavelength longer than about 475 nm (Spooner et al., 1988); and to enhance its detection in emission by the use of optical filters which are selective for ultra-violet, e.g. UG11, UG2, or either of these in conjunction with a 7-59.

These two practices can be profitably introduced to refine conventional R-Γ (R-ß) partial bleach:

1) By carrying out the partial bleach with full sun filtered through a long wavelength pass filter cutting at 475 nm or longer, e.g. GG475 or Chris James 101 (a theatrical filter). Bleaching times of the order of tens of minutes are sufficient to ensure that the 325°C peak is completely removed but that other components are unaffected. This component is thus effectively totally bleached.

2) By using an ultra-violet filter, as described above, during glow out.

We have tried out these modifications on a range of quartz sediments drawn from Australian sites. We have already reported (Prescott and Purvinskis 1991) that application of the procedures yields zero age for modern sites that formerly gave non-zero ages. Zero age

Figure 1.
Schematic, showing the application of conventional partial bleach to finding equivalent dose D_{eq} (after Wintle and Huntley, 1982)

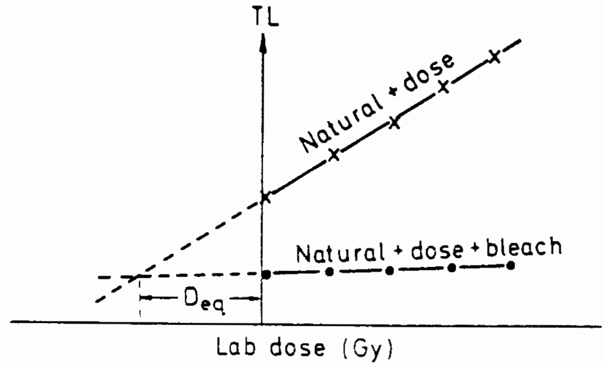
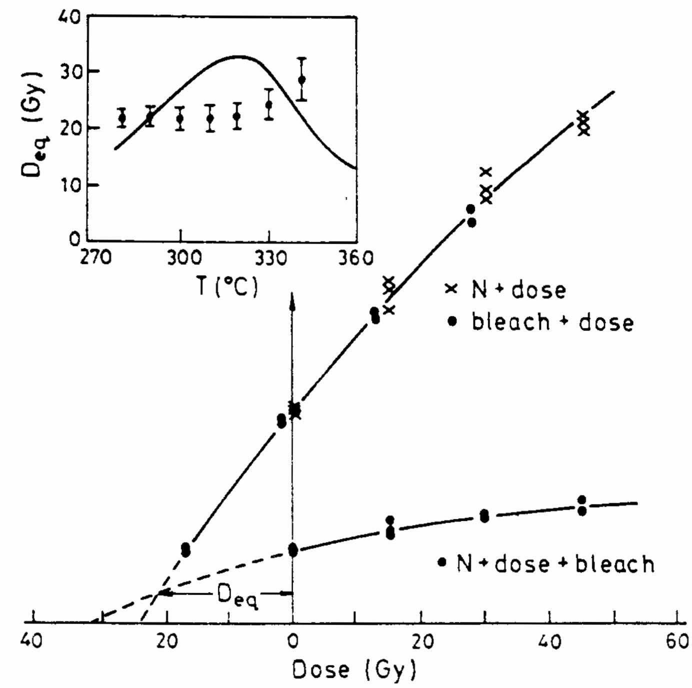


Figure 2.
Dose curves for sample TC2S/65 to which selective bleach procedures, as described in the text, have been applied. The inset shows a portion of the natural glow curve and the corresponding plateau. The rise on the upper side of the peak is attributed to the presence of the tail of the unbleached 375 °C peak.



recovery was one of the tests proposed by Wintle and Huntley (1982) in their early review paper on TL dating of sediments.

So far as the use of u-v filters is concerned, we have found that the degree of selectivity of the 325°C peak differs from sample to sample. In many of them (such as PJ1ES/75 shown in figure 1 of Prescott and Fox, 1990) the background of unwanted peaks is reduced by a factor of five or more with respect to the 325°C peak. In samples where a long-lived peak of lower temperature is present, it interferes strongly since its emission lies within the pass band of the above filters; also it is not easily reduced by bleaching. In other samples, e.g., our Le Fevre Peninsula sequence, the 325°C peak is hardly present at all.

These latter difficulties would be present, of course, whether the selective bleach modifications were applied or not. The new procedures should result in at least some improvement in the estimates of equivalent dose in all cases.

The selectivity of the 325°C peak can be further improved by heating as slowly as practicable, so as to reduce thermal quenching (Wintle 1975) which affects this peak more than others (Spooner personal communication, 1992). We are grateful to A.D. Franklin for drawing our attention to this aspect.

Curve fitting

As indicated above, the partial bleach method requires the (natural + dose) growth curve and (natural + dose + bleach) growth curve to be extrapolated. The possibility of consequent extrapolation errors is well-known and this has been extensively discussed in the literature on TL and ESR. This problem becomes the more challenging, the further the growth curves depart from linear. Procedures to minimise extrapolation errors have been widely discussed and are summarised elsewhere. (Berger 1988, Prescott et al., 1993).

The estimate of equivalent dose can be improved by reducing extrapolation errors using the fitting technique first suggested by Valladas and Gillot (1978). Faced with saturating dose curves for heated materials, they used the shape of the second-glow dose curve to model the missing continuation of the first-glow dose curve for doses less than the natural dose N, making allowance for a change in sensitivity after heating. Readhead (1982; 1984; 1988) independently applied and developed a similar idea for sediments; and further developments have been described by Huntley et al. (1993), or Prescott et al., (1993).

An example of the application of the foregoing techniques to a quartz sample, TC2S/65, from the aeolian infill of an earthquake scarp near Tennant Creek, Australia, is shown in figure 2. Bleaching was 30 minutes of natural sunlight through a Chris James 101 yellow filter with a cut-off to 1% at 475 nm. The optical filter was UG11+7-59, the photomultiplier 9635QA and the heating rate 5 K/s. The equivalent dose is 21 ± 1 Gy and the TL age 14 ± 1 ka.

Further comment

The foregoing applies to quartz. We have found no samples where the 325°C peak was not removed to a negligible level in bleaching times of the order of minutes of full sun. However, as was shown by Robertson et al. (1991) in a study of a representative collection of feldspars, there appears to be little evidence in the alkali feldspars for the existence of any readily bleachable peak with behaviour similar to that of the 325°C peak in quartz, although there was evidence for it in an oligoclase and a suggestion that easy bleaching may be associated with anomalous fading. The optical modifications will therefore not necessarily improve the estimates of equivalent dose in feldspars or undifferentiated mineral samples.

A propos of quartz, it should be noted that most ultraviolet filters also transmit in the red. Since many quartz samples emit in the red (Huntley et al., 1988), unwanted light may be recorded unless this possibility is provided for.

One of the tests suggested by Wintle and Huntley (1982) for TL dating methods was that there should be an age plateau covering a range of temperatures, indicating that the TL originates from states of long lifetime. This test needs restating for selective bleach in quartz because we are most probably dealing with a single trap. We have found that there is a plateau covering the width of the 325°C peak and we should be concerned if there were not. The plateau for TC2S/65 is shown as an inset in figure 2.

Wintle (1975) shows that the lifetime of this level is about 30 Ma and Spooner (personal communication 1992) finds 20 Ma; this would appear to remove the uncertainty in the stability of the TL. We have found no evidence for anomalous fading on limited tests, although we note in passing that there is some evidence for long term fading in the 280°C peak.

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