Selection of integration time intervals for quartz OSL decay curves

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1. Introduction

In the dating of quartz grains using optically stimulated luminescence (OSL) dating protocols, an initial integral of the OSL decay curve is used for the calculation of equivalent dose, once a background integral has been subtracted. Because the OSL signal commonly contains a number of exponentially decaying components, the exact choice of time intervals used for the initial-signal and background integrals determines the composition of the net signal. Here we investigate which combination of time intervals will produce the net signal most dominated by the fast OSL component, while keeping an acceptable level of precision. Using a three-component model of OSL decay, we show that for a specified level of precision, the net signal most dominated by the fast component can be obtained when the background integral immediately follows the initial signal and is approximately 2.5 times its length. With this 'early-background' approach, the contribution of slow components to the net signal is virtually zero. We apply our methods to four samples from relatively young deposits. Compared to the widely used 'late-background' approach, in which the background integral is taken from the last few seconds of OSL, we find less thermal transfer, less recuperation and a higher proportion of aliquots yielding an equivalent dose in agreement with expectations. We find the use of an early background to be a simple and effective way of improving the accuracy of OSL dating, and suggest is should be used in standard protocols.

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ABSTRACT

In quartz optically stimulated luminescence (OSL) dating protocols, an initial integral of the OSL decay curve is used in the calculation of equivalent dose, once a background integral has been subtracted. Because the OSL signal commonly contains a number of exponentially decaying components, the exact choice of time intervals used for the initial-signal and background integrals determines the composition of the net signal. Here we investigate which combination of time intervals will produce the net signal most dominated by the fast OSL component, while keeping an acceptable level of precision. Using a three-component model of OSL decay, we show that for a specified level of precision, the net signal most dominated by the fast component can be obtained when the background integral immediately follows the initial signal and is approximately 2.5 times its length. With this 'early-background' approach, the contribution of slow components to the net signal is virtually zero. We apply our methods to four samples from relatively young deposits. Compared to the widely used 'late-background' approach, in which the background integral is taken from the last few seconds of OSL, we find less thermal transfer, less recuperation and a higher proportion of aliquots yielding an equivalent dose in agreement with expectations. We find the use of an early background to be a simple and effective way of improving the accuracy of OSL dating, and suggest is should be used in standard protocols.

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2. Samples and equipment

In this study we make use of four samples from the Netherlands. The samples are all relatively young, and were deposited under less than ideal bleaching conditions. Since different components bleach at different rates, we expect the calculated ages to depend on the choice of time intervals used. Two of the samples also benefit from good age control.

- Sample NCL-3505030 is from a recent floodplain deposit of the River Waal. Historical maps of the area indicate that the section of floodplain from which the sample was taken was formed between 1723 and 1810 AD (Middelkoop, 1997; Bakker et al., 2007).
- Sample NCL-1109004 is from a storm-surge sediment (consisting mostly of sand) collected from the coastal dunes of North Holland. A large series of OSL dates from the site indicate that the sample was deposited in the late 18th century, and a comparison with documentary sources suggests a likely date of deposition of AD 1775 or 1776 (Cunningham et al., 2009).
- Sample NCL-1107136 is from a very young embanked floodplain of the River Waal (Hobo et al., 2010). Stratigraphically consistent OSL ages for the site have been provided by Wallinga et al. (2010), from which we can be confident that the deposition age is ~55 a.
- Sample NCL-9908154 comes from sandy sediments sampled just below a Medieval rampart structure near Nijkerk (Doesburg et al., 2010). Depositional environment, bleaching conditions and age of the sample are not known.

Prior to measurement, samples were sieved and treated with HCl, H2O2 and HF to isolate the quartz fraction. OSL measurements were carried out on Risø TL-DA-15 readers (Bøtter-Jensen et al., 2000). Stimulation was with 470 nm blue diodes with a power at the sample position of ~35 mW cm⁻². One reader had a higher stimulation power, for which corrections were made in analysis. Irradiation was with ⁹⁰⁶Sr/⁹⁰⁶Y beta sources providing dose rates between 0.028 and 0.14 Gy s⁻¹ to quartz grains at the sample position. The IR diodes emitted at a wavelength of 875 nm and power of ~116 mW cm⁻². A 7.5 mm Hoya U340 detection filter was used.

OSL measurements are based on the SAR protocol of Murray and Wintle (2000, 2003), details of which are given in Table 1. OSL was measured using a channel step-size of 0.05 s unless stated (this step-size is also used in the calculations of Section 3). Preheat conditions were selected on the basis of a thermal transfer test (Section 4.3). The grainsize used was 180–212 μm (NCL-1109004 and NCL-9908154), 212–250 μm (NCL-3505030), and 180–250 μm (NCL-1107136), with each aliquot containing about 200–300 grains. Three samples were expected to indicate a dose of less than 0.5 Gy, for which it is not necessary to ascertain the saturation point of the dose–response curve. For this reason, and to reduce measurement time, the regenerative dose curve for these three samples was constructed with a single (small) given dose and forced through the origin (see chapter 6 of Banerjee et al. (2000), with an initial integral of the decay curve (~0–0.30 s) usually taken as indicative of the fast component signal, once a late background (e.g. 36–40 s) has been subtracted (and corrected to the length of the initial signal). Using the last few seconds of the decay as background adequately removes photomultiplier dark noise and stimulation light leakage from the signal, and also subtracts the majority of the slow component. The length of the initial signal is usually kept short, because the shorter it is, the larger the proportion of fast component in the net signal.

However, as the fast component is usually the most rapidly decaying, it follows that to maximise the proportion of fast component in the net signal, the time interval used for the background subtraction should immediately follow that of the initial signal. Such a procedure has been hinted at before (Aitken and Xie, 1992; Singhvi and Lang, 1998; Banerjee et al., 2007), but has not yet become standard practice, perhaps because of the detrimental effect on measurement precision. No comprehensive analysis of time-interval choice has yet been published, so we explore this topic in the following sections.

3. Methods

3.1. Early-background subtraction

Standard practice for selection of integration time intervals follows Banerjee et al. (2000), with an initial integral of the decay curve (e.g. 0–0.30 s) usually taken as indicative of the fast component signal, once a late background (e.g. 36–40 s) has been subtracted (and corrected to the length of the initial signal). Using the last few seconds of the decay as background adequately removes photomultiplier dark noise and stimulation light leakage from the signal, and also subtracts the majority of the slow component. The length of the initial signal is usually kept short, because the shorter it is, the larger the proportion of fast component in the net signal.

However, as the fast component is usually the most rapidly decaying, it follows that to maximise the proportion of fast component in the net signal, the time interval used for the background subtraction should immediately follow that of the initial signal. Such a procedure has been hinted at before (Aitken and Xie, 1992; Singhvi and Lang, 1998; Banerjee et al., 2007), but has not yet become standard practice, perhaps because of the detrimental effect on measurement precision. No comprehensive analysis of time-interval choice has yet been published, so we explore this topic in the following sections.

3.2. Selection of time intervals

The choice of channels used for defining the ‘initial-signal’ and ‘background’ integrals determine the proportion of each component in the net signal, and the relative error due to counting statistics. Moreover, for any choice of time intervals the proportion

<table>
<thead>
<tr>
<th>Step</th>
<th>Treatment</th>
<th>NCL-3505030</th>
<th>NCL-1109004</th>
<th>NCL-1107136</th>
<th>NCL-9908154</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dose</td>
<td>N, 2.2, 0, 2.2 Gy</td>
<td>N, 3.2, 0, 3.2 Gy</td>
<td>N, 3, 0, 5 Gy</td>
<td>N, 5, 10, 15, 0, 5 Gy</td>
</tr>
<tr>
<td>2</td>
<td>Preheat</td>
<td>200 °C for 10 s</td>
<td>180 °C for 10 s</td>
<td>200 °C for 30 s</td>
<td>240 °C for 10 s</td>
</tr>
<tr>
<td>3</td>
<td>IR bleach (875 nm)</td>
<td>175 °C for 40 s</td>
<td>125 °C for 40 s</td>
<td>125 °C for 40 s</td>
<td>125 °C for 20 s</td>
</tr>
<tr>
<td>4</td>
<td>OSL (470 nm)</td>
<td>125 °C for 40 s</td>
<td>125 °C for 40 s</td>
<td>125 °C for 40 s</td>
<td>125 °C for 20 s</td>
</tr>
<tr>
<td>5</td>
<td>Test dose</td>
<td>2.2 Gy</td>
<td>3.2 Gy</td>
<td>5 Gy</td>
<td>5 Gy</td>
</tr>
<tr>
<td>6</td>
<td>Cutheat</td>
<td>200 °C</td>
<td>170 °C</td>
<td>200 °C</td>
<td>220 °C</td>
</tr>
<tr>
<td>7</td>
<td>IR bleach (875 nm)</td>
<td>175 °C for 40 s</td>
<td>125 °C for 40 s</td>
<td>125 °C for 40 s</td>
<td>125 °C for 20 s</td>
</tr>
<tr>
<td>8</td>
<td>OSL (470 nm)</td>
<td>125 °C for 40 s</td>
<td>125 °C for 40 s</td>
<td>125 °C for 40 s</td>
<td>125 °C for 20 s</td>
</tr>
<tr>
<td>9</td>
<td>OSL bleach (470 nm)</td>
<td>220 °C for 40 s</td>
<td>180 °C for 40 s</td>
<td>220 °C for 40 s</td>
<td>250 °C for 40 s</td>
</tr>
</tbody>
</table>

* This protocol used a 20 s IR bleach during the preheat and cutheat steps (see Wallinga et al., 2010).
of each component in the net signal will vary between aliquots due to variations in the intensity and decay rate of each OSL component between grains. To understand how the composition of the net OSL signal is influenced by the choice of integration time intervals, we discuss first a simulated decay curve. The simulated curve used here consists of three exponentially decaying components of the form \( n_0 a_i \exp(-a_i t) \), where \( t \) is time (s), \( n_0 \) is the initial population of component \( i \), and \( a_i \) is the decay rate of component \( i \). The decay rates used here (\( a_1 = 2.2 \text{ s}^{-1} \), \( a_2 = 0.44 \text{ s}^{-1} \), \( a_3 = 0.02 \text{ s}^{-1} \)) were determined during a previous curve-fitting.
exercise (Cunningham and Wallinga, 2009), and are broadly representative of the fast, medium and slow 2 components of Jain et al. (2003) under (470 nm wavelength) stimulation light intensity of $\sim 35$ mW cm$^{-2}$. The populations $n_0$ in this example are 100, 100 and 1000; i.e. the same trap populations for the fast and medium components, with a much larger slow component. The simulated decay curve was produced with 0.05 s time-steps, and for clarity no noise was included. Using this simulated decay curve, the contribution of each component to the net OSL signal can be calculated for every time-interval combination used for signal and background collection. The error due to counting statistics can also be determined, and is given henceforth as the Relative Standard Error (RSE) term of Li (2007).

The results of this exercise can be seen in Fig. 1. In Fig. 1A, the proportion of fast component in the simulated net OSL signal is shown as a function of the time interval used for the initial signal and the time interval used for the background subtraction (which is taken immediately following the initial signal). The horizontal plane indicates the equivalent value calculated using the ‘late-background’ time intervals (0–0.30 s for the initial signal, 36–40 s for the background). Fig. 1B and C show the same for the medium and slow components. It is clear that the slow component is almost wholly removed with any combination of early-background time intervals. It is also evident from these plots that the maximisation of the fast component and minimisation of the medium component is best achieved by using a short time interval for the initial signal, and a short time interval for the background. However, the use of short time intervals, especially for the background, leads to a reduction in the precision with which the net signal is known (Fig. 1D). It is therefore necessary to introduce some criteria for an acceptable level of precision. The best combination of time intervals is the one which gives the net signal with the largest percentage of fast component, while keeping the RSE below this threshold. Some criteria are therefore needed to select the best channel combination. As an example, we have plotted an RSE threshold of 5% as a horizontal plane on Fig. 1D. The combination of time intervals which gives the largest proportion of the net signal from the fast component while satisfying the RSE criteria is indicated by the black square on Fig. 1A.

4. Results

4.1. Validation of the 3-component model

Example (regenerative) decay curves have been fitted with three (unconstrained) components, and are plotted in Fig. 2. The parameters vary slightly between each plot, as expected. All samples have a fast and slow component. While sample NCL-9908154 (Fig. 2D) has little or no medium component, a three-component model can still be applied (which mean the $n_{02}$ parameter will equal zero, or be very small).

4.2. Calculations for real data

In order to perform time-interval calculations for real OSL decay curves, it is necessary to first estimate the magnitude of the various components. Here we have applied a simple curve-fitting routine to decay curves following a regenerative dose given to 24 aliquots of each sample. By assuming a maximum of three components are present, and their photo-ionisation cross-sections are predetermined, it is computationally simple to gain an approximation of the magnitude of each component using a non-negative least squares method. As no variation in decay rate $\alpha$ is permitted, the outcome does not give a rigorous fit, but provides a good approximation of the magnitude of each component. With an estimate of the decay-curve composition, the calculation of the optimal integration time intervals can be done according to the method outlined in Section 3.2, which now depends solely on the desired level of precision. The influence of desired precision on time-interval selection is shown in Fig. 3, for two aliquots of sample NCL-3505030. For aliquot (a), a reduction in the precision threshold (an increase in RSE) allows the proportion of fast component in the net signal to be increased, which is achieved by decreasing the length of the integration time intervals for both the initial-signal and (subsequent) background intervals. However, it is apparent that the improvement in the percentage of fast component gained through a reduction in precision suffers from diminishing returns, with little benefit obtained by increasing the RSE beyond 2.5%. Fig. 3B shows the same information for an aliquot with a less dominant fast component. In this case, a significant improvement in the proportion of fast component can be achieved by accepting less precision.

It is important to note that for both aliquots shown in Fig. 3 the implied range of suitable integration lengths is similar. Furthermore, as the RSE threshold is changed, the relationship between signal length and background length is similar for all four samples. This can be seen more clearly in Fig. 4, which plots the optimum background length to signal length ratio for 24 aliquots of each sample, as a function of RSE threshold. Each strand represents one

![Fig. 3. The integration time intervals which result in the net signal with the largest proportion of fast component, for a given RSE threshold. (A) and (B) show calculations for different aliquots of sample NCL-3505030. The proportion of the net signal composed of fast component, resulting from the specified combination of time intervals, is shown on the right-hand axis. Insets show the OSL decay curves for these aliquots, which were fitted with three exponential functions so that the effects of time-interval selection could be ascertained.](image-url)
Fig. 4. The calculated ratio of background length to initial-signal length which gives the net signal with the maximum possible proportion of fast component, for RSE thresholds between 1 and 15% on the (first) regenerative OSL signal. Each line represents one aliquot, the decay curve of which has been fitted with three exponential functions to represent the fast, medium and slow components so that the effects of using different integration intervals can be calculated. Within each sub-plot, the lines are shaded according to the estimated strength of the fast component ($n_{0f}$) for that aliquot, with darker shading for larger fast components. The shading scale differs between samples. The dashed line indicates a ratio of 2.5. Also shown is the average percentage of fast component in the net signal (open symbols, plotted on the second $y$-axis), when calculated using the optimum integration lengths (this means that the integration lengths vary between aliquots at any one threshold). OSL measurements used in plot (D) were carried out on a reader with a higher stimulation power.

Our OSL measurements are preceded by a preheat, the purpose of which is to empty thermally unstable OSL traps which would otherwise contribute to the signal. However, preheating can lead to thermal transfer of charge from light-insensitive traps (which may contain large accumulated doses), to the traps responsible for OSL (Wintle and Murray, 2006). This is a particular problem for young samples given their comparatively small $D_e$. When this occurs following the regenerative doses, it is detectable in the OSL following a zero dose (recuperation). Based on curve fitting the OSL signals, Jain et al. (2003) and Tsukamoto et al. (2003) found the fast component to show far less recuperation than the medium or slow components.

If the $D_e$ calculated using the early background is indeed a better reflection of the fast component $D_e$, we would expect to see less thermal transfer and recuperation than with the late background. To test for thermal transfer, we first bleached eight aliquots of each sample with 470 nm LEDs at room temperature for 40 s, which was repeated after a 1000 s pause. This treatment aims to empty
trapped charge giving rise to the fast (and medium) component, whilst leaving a large part of the less light-sensitive trapped charge in place. A low (140 °C) preheat was then given, followed by OSL at 125 °C. Successive preheats to higher temperatures (160 °C, 180 °C, ..., 220 °C) were then applied, each followed by an OSL measurement. Finally the OSL signal was reset by a high temperature bleach, after which the OSL response to a single dose point was measured to allow translation of the thermal transfer OSL signals to an approximate De. The cumulative De indicates the amount of thermal transfer at each preheat temperature, albeit with a slight temperature shift caused by the earlier preheats. This procedure is explained fully in Wallinga et al. (2010), and differs slightly from the approach of Jain et al. (2004) and Truelsen and Wallinga (2003) in that no test dose is given. The results clearly show that less thermal transfer is measured if the early background is used (Fig. 5C and D). Measurements of recuperation also yield lower values for the early background than for the late background (Table 2).

4.4. Equivalent dose

The use of the early background has a significant effect on the De distribution for three of the samples shown here, with the fourth sample (NCL-9908154) showing little difference between early and late-background results. For fluvial sample NCL-3505030 (Fig. 6A–C), the reduction in the measured recuperation values when the early background is used lead to more aliquots passing the acceptance criteria. There is a reduction in De compared with the late background for most aliquots, which could be due to the

![Fig. 5. (A, B) Example OSL decay curves for two samples, showing the natural and regenerative signals. Also shown are the integration intervals suggested in this paper to be suitable for these samples. (C, D) The thermally transferred dose (given as a percentage of the expected dose) as a function of preheat temperature, details in Section 4.3. (E, F) Results of dose recovery tests following a given dose of ~3.2 Gy, under the same conditions used for measurement of De.]

<table>
<thead>
<tr>
<th>Sample</th>
<th>Time intervals</th>
<th>Recycling ratio</th>
<th>Recup. dose (Gy)</th>
<th>No. accepted/total aliquots</th>
<th>No. giving expected De</th>
<th>Dose rate (Gy ka⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCL-3505030</td>
<td>Late BG</td>
<td>0.996 ± 0.016</td>
<td>0.033 ± 0.006</td>
<td>14/48</td>
<td>2</td>
<td>1.31 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>Early BG</td>
<td>0.980 ± 0.020</td>
<td>0.011 ± 0.005</td>
<td>21/48</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>NCL-1109004</td>
<td>Late BG</td>
<td>0.997 ± 0.010</td>
<td>0.007 ± 0.003</td>
<td>30/48</td>
<td>12</td>
<td>1.37 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>Early BG</td>
<td>0.988 ± 0.015</td>
<td>-0.008 ± 0.006</td>
<td>15/48</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>NCL-1107136</td>
<td>Late BG</td>
<td>0.972 ± 0.009</td>
<td>0.034 ± 0.006</td>
<td>23/84</td>
<td>11</td>
<td>2.06 ± 0.06</td>
</tr>
<tr>
<td></td>
<td>Early BG</td>
<td>0.970 ± 0.009</td>
<td>0.026 ± 0.004</td>
<td>25/84</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>NCL-9908154</td>
<td>Late BG</td>
<td>1.022 ± 0.009</td>
<td>0.011 ± 0.002</td>
<td>30/38</td>
<td>—</td>
<td>1.01 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>Early BG</td>
<td>1.020 ± 0.014</td>
<td>0.007 ± 0.003</td>
<td>26/38</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

* Agreement within 2σ. Uncertainty in the dose rate has been included, hence the small difference with Fig. 6.

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reduction in thermal transfer and/or smaller contributions from less light-sensitive components. More aliquots, and a higher proportion of aliquots, give results in agreement with the expected \( D_e \). For storm-surge deposited sample NCL-1109004, the impact of partial bleaching and thermal transfer are less obvious, but the early background still has a beneficial effect on \( D_e \). While less aliquots pass acceptance criteria than with the late background, those which remain show a tighter distribution, and are largely in agreement with the expected \( D_e \) (Fig. 6D).

Probability density functions (PDFs) of \( D_e \) for samples NCL-1107136 and NCL-9908154 can be seen in Fig. 7, along with example decay curves. For NCL-1107136, the use of an early background appears increase the dominance of the initial peak in the PDF, and increases the number of aliquots giving \( D_e \) within the expected range (Table 2). The early-background distribution for sample NCL-9908154 is largely unchanged from the late-background distribution, although the use of short intervals for the early-background in this case leads to greater error terms, and hence a smoother looking curve. The similarity of the early- and late-background results for this sample is not unexpected, given the absence of medium component, and limited amount of slow component, in the OSL decay curve (Fig. 2D).

5. Discussion

5.1. Implications of early-background subtraction for young samples

For the young samples studied here, it is clear that the use of the early-background time intervals has a beneficial effect on the \( D_e \) distribution, by increasing the number and proportion of accepted aliquots which have \( D_e \) consistent with a single population, and also with the expected \( D_e \). This is achieved through two effects:

1. The almost complete removal of the slow component from the net signal. The proportion of the net signal belonging to the slow component is an order of magnitude less with the early background compared to the late background (Fig. 1C). This results in a significant and consistent reduction in the measured amounts of thermal transfer and recuperation, and is likely to lessen the severity of partial bleaching in the \( D_e \) distribution. Differences in the precise choice of early-background intervals have a minor effect on the \( D_e \) distribution, which implies that the removal of the slow component is the most important effect (since the slow component is removed by any combination of early-background time intervals). Ballarini et al. (2007) also came to this conclusion when testing integration intervals for single-grain measurements, although the 525 nm stimulation wavelength they used would have lead to a larger difference in the photo-ionisation cross-sections of the fast and medium components (Singarayer and Bailey, 2004).

2. Improved auto-weighting of aliquots according to the dominance of the fast component. When the early background is used, aliquots with little or no fast component will tend to give imprecise \( D_e \). The resulting \( D_e \) distribution is then naturally weighted towards aliquots with a strong fast component, as they retain a relatively precise \( D_e \). Any age model then applied to the \( D_e \) dataset, provided it takes account of the errors on each aliquot (e.g. central and minimum age models of Galbraith et al. (1999)), will be preferentially influenced by the desirable, fast-component dominated aliquots. This may result, for instance, in a reduction in the number of apparent age populations and an increase in precision on the age-model derived \( D_e \).
Use of an early background may also reduce the feldspar component of the ‘quartz’ signal. Although standard laboratory preparation for quartz includes chemical treatment to remove feldspars, there can often be a remnant signal from, for instance, feldspar inclusions within quartz grains (Huntley et al., 1993). Since feldspar OSL decay is slower than quartz under 470 nm stimulation (e.g. Wallinga et al., 2002), the use of an early background will remove more of the feldspar signal than with a late background.

5.2. Sensitivity in the choice of early-background time intervals

Complete isolation of the fast component is not possible with any combination of integration time intervals, if there are other components present in the signal. The percentage of each component in the net signal also varies dramatically between aliquots, due to inter-grain differences in the strength of each component and the absorbed dose. External factors such as stimulation light intensity (and wavelength) and the level of dark noise also have a significant effect. However, for the practical purpose of maximising the fast component under 470 nm stimulation (e.g. Wallinga et al., 2002), the use of an early background will remove more of the feldspar signal than with a late background.

5.3. Implications for older samples

The removal of the slow components by using an early background is highly beneficial for young samples, because either through partial bleaching or thermal transfer the slow components are likely to cause most scatter in \( D_e \). Furthermore, weak signal-to-noise ratios with young samples make the extraction of the fast component through curve-fitting challenging (Cunningham and Wallinga, 2009). The early-background method therefore represents an extremely simple and efficient way of obtaining a predominantly fast-component derived signal.

When it comes to older samples, other sources of scatter, rather than partial bleaching, are likely to be more important. Several authors have noted a significant underestimation of age, which becomes more apparent for older samples (Murray et al., 2008; Stokes et al., 2003). Singarayer and Bailey (2003) identified a slow component ‘S2’ which appeared to be thermally unstable, and Rhodes et al. (2006) considered this component to be causing \( D_e \) underestimates in their bulk OSL signal. Where \( D_e \) underestimation is caused by an unstable slow component, the use of an early background is likely to be beneficial, and lead to an increase in \( D_e \) compared to the late-background approach. Recently however,

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Fig. 7. Examples in the use of an early background, using samples of different OSL sensitivity. On the left, sample NCL-1107136 (very young fluvial sample); on the right, sample NCL-9908154. (A) and (B) show typical OSL decay curves, with the early-background intervals indicated (see Section 4.2). Please note that the channel step-size differs between these samples (0.02 s and 0.025 s, both shorter than in the previous examples (Fig. 5)). In addition, OSL measurements for plot (B) were carried out under higher stimulation power, leading to faster OSL decay. (C) and (D) show probability density functions of the \( D_e \) distributions calculated using the indicated early-background intervals (shaded area) and the standard late-background intervals (solid line). The PDFs have been normalised by area. Numbers in brackets indicate [number of accepted aliquots/total number of aliquots measured].
Bailey (2010) raised the possibility of an unstable medium component, which may be present in some samples. While the early-background approach is an improvement on the late-background approach for such samples, the brightness of the OSL signals for most older samples would facilitate sophisticated methods of fast-component isolation to be used instead. This could be approached by curve fitting of the OSL signal (although this is by no means simple, see Wallinga et al., 2008); or through IR stimulation (Bailey, 2010) or IR depletion (Jain et al., 2005).

5.4. The ultrafast component

Jain et al. (2003, 2008) have detected an ultrafast OSL component in several quartz samples. The low thermal stability of the ultrafast component makes it unsuitable for dating, and its presence in regenerative signals can lead to dose underestimation. Even a small ultrafast component will have a significant effect on $D_e$. As the signal from the ultrafast component is completely removed after 0.15 s, it is always contained within the initial-signal interval. As such, the proportion of the net signal constructed from the ultrafast component is largely unaffected by the choice of integration time intervals, but is negatively correlated with net signal intensity. The use of an early background therefore has no adverse effects with respect to the ultrafast component compared to a late background. To avoid influence of the ultrafast component on the $D_e$ estimate, IR bleaching may be beneficial (Wallinga et al., 2010).

6. Conclusion

When using integration intervals of CW-OSL data for the purpose of dating, the choice of time intervals influences the proportion of each OSL component in the net OSL count, and the error due to counting statistics. We have tried to identify which combination of time intervals should be used for dating, when the stimulation wavelength is 470 nm, and conclude that:

1. By using a background interval which immediately follows the interval for the initial signal (rather than at the end of the stimulation period), the proportion of fast component in the net OSL count is much improved, while the proportion of slow components is diminished by approximately one order of magnitude.

2. For a specified (and practical) level of precision, the proportion of the net OSL count coming from the fast component can be maximised by using a background interval approximately 2.5 times longer than the initial signal (and immediately following it).

For two young samples of known age, we found that (with the stimulation power at 35 mW cm$^{-2}$) an initial signal of 0–0.40 s with background interval from 0.40 to 1.40 s produced results showing less thermal transfer, less recuperation, tighter $D_e$ distributions and more aliquots with $D_e$ in line with the expected $D_e$ than using the alternative, late-background time intervals (samples NCL-3505030 and NCL-1109004). We consider this improvement to be largely due to the almost complete removal of the slow components from the net signal. Given that the use of an early background is extremely easy to implement and does not seem to have any detrimental effects, we suggest it should be used routinely to improve the accuracy of quartz OSL dating.

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