Quartz fast component optically-stimulated luminescence: towards routine extraction for dating applications

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Abstract

Using an uncontaminated fast component is a key for improving the reliability of quartz OSL dating for many deposits. So far no approach to extract the fast component of quartz OSL has routinely been adopted for dating practice. Key challenges for extracting fast components are (1) the difficulty of finding a unique solution in curve-fitting deconvolution of OSL decay curves and (2) the relatively poor dating precision when using experimental fast component extraction. Here, a simple mathematic solution for fast component extraction is presented that is not relying on curve-fitting deconvolution and can easily be adopted into routine dating practices. By using specifically selected data points from smoothed OSL decay curves, the precision of equivalent doses calculated using the extracted fast component can be improved over equivalent doses calculated using bulk OSL. The fast component extraction is tested on a group of age-constrained samples containing both insufficiently bleached and sufficiently bleached deposits. Fast component OSL ages are as accurate as bulk OSL ages for the sufficiently bleached deposits, but more accurate for samples where bulk OSL is affected by insufficient bleaching. We also demonstrate how using a curve smoothing procedure can improve dating precision in case of both sufficiently and insufficiently bleached deposits.

Keywords: OSL dating, fast component

1. Introduction

Optically stimulated luminescence (OSL) dating of quartz has developed as one of the key techniques for dating the late Quaternary, especially since the advent of the single aliquot regenerative dose (SAR) protocols (Murray and Wintle, 2000). To establish the age of depositional events, green or blue light stimulation of quartz is used in a wide variety of environments to determine the dose acquired since a crystal was latest exposed to sunlight. Quartz OSL has been shown to consist of multiple components (Smith and Rhodes, 1994). Following Bailey et al. (1997) and depending on optical sensitivity, fast (OSL_f), medium (OSL_m) and slow (OSL_s) components can be differentiated. Routine practice in OSL dating utilizes signal from the initial part of OSL decay curves that is usually comprised of multiple components, though the SAR protocol has been shown to work particularly well for OSL_f dominated quartz (Wintle and Murray, 2006).

Two characteristics render OSL_f especially suitable for sediment dating: (1) the high thermal stability (e.g., Singarayer and Bailey, 2003; Shen et al., 2011) and (2) the high optical sensitivity. Large contributions of OSL_m and OSL_s in OSL dating can lead to inaccurate age estimates either due to thermal instability (Bailey et al., 2003; Jain et al., 2003; Li and Li, 2006; Shen and Mauz, 2009) or insufficient bleaching induced by the reduced optical sensitivity. The latter is of great concern particularly for dating sediments laid down after a short transport distance in turbid water where the intensity and wavelength of sunlight is significantly attenuated (Berger, 1990) and for relatively young deposits. Isolating OSL_f represents a key procedure to improving the accuracy of quartz OSL dating in such circumstances.

Existing techniques to identify and characterize OSL components are of limited use for dating applications. Curve-fitting deconvolution analysis of OSL decay curves is mathematically challenging and requires extensive tests to produce meaningful results (e.g., Choi et al., 2006). Experimental extraction of OSL_f by high temperature infra-red light stimulation often takes long measurement time (e.g., Jain et al., 2005) and yields a low signal/noise ratio (Bailey, 2010). In practice, all these OSL_f dating approaches result in a significantly reduced equivalent dose (D_e) precision.

Here, a simple mathematic method is presented to extract OSL_f from continuous wave OSL (referred as OSL thereafter unless defined otherwise) using predefined parameters for OSL components (cf. Li and Li, 2006; Cunningham and Wallinga, 2009). The method is coded in Matlab® program (see supplementary file) to perform OSL_f extraction and equivalent dose (D_e) calculation. We test the method with a range of waterlain deposits comprising of insufficiently bleached as well as sufficiently bleached samples. Compared to traditional OSL dating practice the proposed technique leads to an increase in accuracy, is not detrimental to equivalent dose precision, and can even be used for relatively dim samples with low signal-to-noise ratios.

2. Background

Assuming first-order kinetics, decay of quartz OSL, $I(t)$, under continuous wave optical stimulation can be described by the sum of multiple exponential decay components, commonly referred as OSL_f, OSL_m and OSL_s (cf. Bailey et al., 1997):

$$I(t) = \sum_{i=1}^n I_i(t) \quad (1)$$

$$\ln I_i(t) = \ln I_{i0} - \frac{1}{\lambda_i} \times t \quad (2)$$

with $I_i(t)$, I_{i0} and λ_i representing the OSL intensity at time t , initial OSL intensity and the decay constant of the i th component, respectively. The slow component shows minimal decay after a few tens of seconds of optical stimulation with blue light, as commonly used in quartz OSL dating, and can be removed from an OSL decay curve together with background signal through late-light background subtraction (Wintle and Murray, 2006). The resulting decay curve contains OSL_f and OSL_m only. Designate $i=f$ for OSL_f and $i=m$ for OSL_m and using a $\ln I(t)$ scale, OSL_f and OSL_m both decay linearly. Between OSL counting at time t_1 and t_2 ($t_2 - t_1 = dt$), the slopes for the linear decays are:

$$S_f = \frac{\ln I_f(t_2) - \ln I_f(t_1)}{dt} = -\frac{1}{\lambda_f} \quad (3)$$

$$S_m = \frac{\ln I_m(t_2) - \ln I_m(t_1)}{dt} = -\frac{1}{\lambda_m} \quad (4)$$

The slope for $\ln I(t)$ (bulk OSL) is:

$$S = \frac{\ln[I_f(t_2) + I_m(t_2)] - \ln[I_f(t_1) + I_m(t_1)]}{dt} \quad (5)$$

Assigning $p_1 = \frac{I_f(t_1)}{I_m(t_1)}$ and $p_2 = \frac{I_f(t_2)}{I_m(t_2)}$ as the ratios between OSL_f and OSL_m at time t_1 and t_2 , respectively. Replacing $I_m(t_1)$ by $I_f(t_1)/p_1$ and $I_m(t_2)$ by $I_f(t_2)/p_2$ in equation (5) and using equation (3) results in:

$$S = \frac{\ln(\frac{p_1}{p_2})}{dt} + \frac{\ln(\frac{p_2+1}{p_1+1})}{dt} + S_f \quad (6)$$

Replacing $I_f(t_1)$ by $p_1 \times I_m(t_1)$ and $I_f(t_2)$ by $p_2 \times I_m(t_2)$ in equation (5) and using equation (4) results in:

$$S = \frac{\ln(\frac{p_2+1}{p_1+1})}{dt} + s_m \quad (7)$$

Resolving equations (6) and (7) for p_1 and p_2 returns:

$$p_1 = \exp[(s_m - s_f) \times dt] \times p_2 \quad (8)$$

$$p_2 = \frac{\exp[(s_m - S) \times dt] - 1}{\exp[(s_m - s_f) \times dt] - \exp[(s_m - S) \times dt]} \quad (9)$$

The intensities of OSL_f at t_1 and t_2 are, respectively:

$$I_f(t_1) = I(t_1) \times \frac{p_1}{1+p_1} = I(t_1) \times \frac{\exp[(2s_m - s_f - S) \times dt] - \exp[(s_m - s_f) \times dt]}{\exp[(2s_m - s_f - S) \times dt] - \exp[(s_m - S) \times dt]} \quad (12)$$

$$I_f(t_2) = I(t_2) \times \frac{p_2}{1+p_2} = I(t_2) \times \frac{\exp[(s_m - S) \times dt] - 1}{\exp[(s_m - s_f) \times dt] - 1} \quad (13)$$

Parameters s_f and s_m are inversely related to the decay constants of OSL_f and OSL_m, respectively, S can be calculated between any two data points of interest, and dt is the time interval between the data points considered. Therefore, OSL_f can be extracted from OSL decay curve using equations (12) and (13).

3. Methods and samples

An OSL_f extraction procedure is developed for quartz OSL measured at 125 °C for 40 s with a 0.16 s integration interval using blue LED stimulation (470Δ30 nm) delivering ~30 mW/cm² at the sample location and coded in Matlab® that can readily be adapted for OSL of different stimulation conditions. The procedure consists of smoothing OSL decay curves using a smoothing function composed of the sum of two exponential decays, removing OSL_s and background from the smoothed OSL by subtracting an exponential function fitted to the last 24 s

of OSL decay curves, and applying predefined s_f and s_m for OSL_f extraction. Only the initial portion of the decay curve (first 8 s here) that consists of significant contributions of OSL_f and OSL_m (cf. Galbraith et al., 1999) is used in the smoothing procedure.

Values of s_f and s_m are derived from photoionization cross-sections (σ) of OSL_f and OSL_m reported for sedimentary quartz originating from widely differing geographic regions (Jain et al., 2003; Singarayer and Bailey, 2003; Durcan and Duller, 2011). The weighted mean σ_f ($2.56 \pm 0.06 \times 10^{-17} \text{ cm}^2$) and σ_m ($4.81 \pm 0.27 \times 10^{-18} \text{ cm}^2$) of the reported values are used (Table S1). The decay constant λ is calculated from σ and the power of stimulating light at the sample location. For a stimulation light source of $470 \pm 30 \text{ nm}$ that delivers $\sim 30 \text{ mW/cm}^2$ power at the sample location, $\lambda_f = 0.55 \pm 0.01 \text{ s}$ and $\lambda_m = 2.93 \pm 0.16 \text{ s}$.

To account for the uncertainties related to the uncertainties of decay constants and counting statistics in OSL_f calculation, a Monte Carlo approach is used. The values of λ_f and λ_m are randomly sampled from normal distributions with mean/standard deviations of 0.55/0.01 and 2.93/0.16, respectively, while $I(t_1)$ and $I(t_2)$ are randomly sampled from normal distributions derived from the background removed OSL and its relevant uncertainty. OSL_f is calculated for each sampling of λ_f , λ_m , $I(t_1)$ and $I(t_2)$ and the average value and standard deviation of 5000 calculations are used as OSL_f and its uncertainty.

Simulated OSL samples are used to guide the development of the OSL_f extraction procedure and test the accuracy of the extraction. The simulated OSL consists of three components and a background signal. The decay constants of the three components have been chosen as $\lambda_f = 0.55 \text{ s}$, $\lambda_m = 2.93 \text{ s}$, and $\lambda_s = 55 \text{ s}$ (Jain et al., 2003; Singarayer and Bailey 2003). To account for Poisson distributed counting statistics, the three components are first summed up and each data point is

then resampled from a Poisson distribution centered at the summed OSL of that data point.

Finally a background randomly sampled from a Poisson distribution with a mean of 9 counts (as derived from the measurement of a blank aliquot) is added for each simulated data point. Three scenarios with different OSL brightness ('bright', 'dim', 'very dim') are simulated (Table S2) to investigate the effect of signal/noise ratios on OSL_f extraction.

Six waterlain deposits collected from the Mississippi Delta and its surrounding areas (Table 1) were used to test the OSL_f extraction procedure for OSL dating. Wax Lake Delta I-1 (WLD I-1) and Wax Lake Delta (WLD I-2) are river-mouth bar deposits and their ages were constrained by aerial photograph interpretation (Shen and Mauz, 2012). OSL ages calculated using bulk OSL of the two samples demonstrate that they are affected by insufficient bleaching (Shen and Mauz, 2012). Paincourtville I-4 (PV I-4) is a natural levee deposit and also affected by insufficient bleaching (Shen et al., 2012). The age of PV I-4 is constrained by a radiocarbon age of a peat underlying the levee deposit (Törnqvist et al., 1996). Chenier Perdue I-1 (CP I-1) and Grand Chenier I-1 (GC I-1) are beach deposits taken from the Louisiana Chenier Plain in the northern Gulf of Mexico coast that was radiocarbon dated (Gould and McFarlan, 1959). Amite River I-1 (AR I-1) is a point bar deposit from an abandoned Amite River in southern Louisiana, USA. For this sample no independent age control is available but stratigraphic constraints place it in the late Pleistocene.

All OSL was measured using a single aliquot regenerative dose (SAR) protocol (Murray and Wintle, 2000) on either a Risø DA-15 B/C TL/OSL reader equipped with 27 blue light-emitting diodes (LEDs) (470Δ30 nm) or a Risø DA-15 TL/OSL reader equipped with 41 blue LEDs for optical stimulation. Both readers deliver ~30 mW/cm² at sample location (90% stimulation power). All aliquots were prepared by mounting quartz to the center 1-2 mm diameter area of 10

mm-diameter stainless-steel discs. Natural radionuclide concentrations of the samples were determined with a high-resolution and low-background gamma spectrometer, and converted to natural dose rate following Adamiec and Aitken (1998).

OSL decay curves from the SAR measurement were analyzed to extract OSL_f . OSL_f integrated over the first 0.32 s (two data points) was used for D_e calculation ($D_{e_OSL_f}$), in addition to D_e estimates from the bulk OSL (integrated over the first 0.32 or 0.8 s, D_{e_bulk}). OSL_f of natural and regeneration dose OSL were normalized by the relevant test dose OSL_f for sensitivity correction. An instrumental error of 1.7% was added in quadrature to the uncertainty of sensitivity corrected OSL_f (cf. Duller, 2007). Uncertainty of D_e was derived using a Monte Carlo approach. D_e acceptance criteria includes (1) recycling ratio and post IR-OSL ratio within 0.9 to 1.1; (2) recuperation <5% except for WLD I-1 and I-2. Dose response curves of the latter two samples were forced through origin (Shen and Mauz, 2012).

4. Fast component extraction

4.1. Reducing OSL variance by smoothing

As a first step for OSL_f extraction OSL decay curves are smoothed. Smoothing of simulated OSL shows that the first 8 s of the decay curves are sufficiently well described when using the smoothing function (Fig. S1).

The simulated OSL is used to quantify the uncertainty of smoothed OSL. Each OSL scenario (Table S2) is simulated 1000 times and subsequently smoothed. For each scenario, the variance of the 1000 simulated OSL curves is divided by the variance of the smoothed OSL and plotted against stimulation time (Fig. 1). The variance ratio is ~65% at the first data point and decreases rapidly to <10% after ~1 s stimulation time. This trend is consistent for all scenarios of OSL

brightness and does not change significantly even if the relative proportion of the three OSL components in the simulated OSL is changed. Therefore, using this empirical relationship, the variance of smoothed OSL can be calculated from the variance of the corresponding unsmoothed OSL.

4.2. Effect of t_1 and t_2 selection on the uncertainty of OSL_f extraction

Counting statistics is a major factor affecting the uncertainty of S . Dependence of the uncertainty of S on t_1 and t_2 is assessed using the simulated OSL. Assuming Poisson distributed counting statistics, the relative standard error (RSE) of S calculated for an OSL consisting of OSL_f and OSL_m only can be approximated as:

$$RSE(S) = \frac{\ln[I_f(t_1) + I_m(t_1)] - \ln[I_f(t_1) + I_m(t_1) - \sqrt{k_1(I_f(t_1) + I_m(t_1))]} + \ln[I_f(t_2) + I_m(t_2)] - \ln[I_f(t_2) + I_m(t_2) - \sqrt{k_2(I_f(t_2) + I_m(t_2))}]}{\ln[I_f(t_2) + I_m(t_2)] - \ln[I_f(t_1) + I_m(t_1)]} \quad (14)$$

where k_1 and k_2 are the ratios of variance of smoothed OSL to variance of unsmoothed OSL at times t_1 and t_2 respectively. These two ratios are included to account for the reduction of OSL variance due to smoothing and their values are obtained from Fig. 1. Because only the initial part of an OSL decay curve is dominated by OSL_f, we considered t_1 in the range of 0 to 0.8 s. $RSE(S)$ generally increases with increasing t_1 , but decreases with an increasing distance between t_1 and t_2 , i.e. dt (Fig. 2). This trend does not change with the brightness of the simulated OSL. Therefore, we used $t_2 - t_1 = 1.92$ s for every t_1 in the OSL_f extraction to achieve a relatively small uncertainty of S .

4.3. Accuracy of OSL_f extraction

The accuracy of the extracted OSL_f is tested against the simulated OSL that was used as model input. Each of the three OSL brightness scenarios (Table S2) is simulated for 200 times. OSL_f integrated over the first 0.32 s is calculated and divided by the model input to obtain a parameter OSL_f ratio. The distribution of the OSL_f ratios for the 200 simulations of each scenario demonstrates that the mean OSL_f ratio is 1 in all three scenarios, but the scatter increases with decreasing brightness, i.e., decreasing signal/noise ratio (Fig. S2). For the ‘bright’ and ‘dim’ scenario, OSL_f ratios all fall within 1.0 ± 0.1 , but for the ‘very dim’ scenario about 30% of calculated OSL_f differ by $>10\%$ from the model input (Fig. S2).

5. Dating application using extracted OSL_f

For the six waterlain deposits, the initial 8 s of empirical OSL are all well described by the smoothing function. $D_e(t)$ plots reveal a rising trend for some aliquots of WLD I-1 and I-2, and a plateau for aliquots of CP I-1, GC I-1 and AR I-1 (Fig. 3). $D_{e_OSL_f}$ is generally lower than or comparable to D_{e_bulk} for WLD I-1, I-2 and PV I-4 (Fig. 4). The mean $D_{e_OSL_f}/D_{e_bulk}$ ratios are 0.52 ± 0.04 , 0.71 ± 0.04 and 0.94 ± 0.01 for the three samples, respectively, all significantly smaller than unity. For the other three samples $D_{e_OSL_f}$ and D_{e_bulk} are comparable for the majority of accepted aliquots.

The $RSEs$ of $D_{e_OSL_f}$ and D_{e_bulk} differ (Fig. 5). WLD I-1 and I-2 have the lowest OSL intensity and largest $RSEs$ of all samples while AR I-1 has the brightest OSL and smallest $RSEs$. For WLD I-1 and I-2, RSE of $D_{e_OSL_f}$ is comparable with RSE of D_{e_bulk} for aliquots with relatively high D_e precision, but larger for aliquots with relatively low precision, which is also shown in the D_e radial plots (Fig. S3). For all the other samples the majority of $RSEs$ of $D_{e_OSL_f}$ are smaller than $RSEs$ of D_{e_bulk} .

The accuracy of OSL_f extraction is affected by counting statistics. Plotting OSL_f recycling ratio against initial OSL intensity of the recycling dose for all analyzed aliquots of the six samples (Fig. 6) clearly shows that the scatter of OSL_f recycling ratio decreases with increasing OSL intensity.

Dating results for the six samples are summarized in Table 1. Overdispersion of CP I-1, GC I-1 and AR I-1 are ~10%, typical of well-bleached deposits. A central age model produced bulk OSL and OSL_f based ages both in good agreement with independent age constraints. Bulk OSL ages of WLD I-1 and WLD I-2 are older than expected while minimum ages derived from OSL_f of these two samples are in agreement with expectations.

6. Discussion

The accuracy of OSL_f extraction is affected by multiple factors. There is a strong dependence of the accuracy on OSL counting statistics. The low intensity OSL yields the least accurate result in OSL_f extraction (Fig. S2) and less accurate OSL_f derived recycling ratios (Fig. 6). When applying the technique in OSL dating, OSL_f derived recycling ratios offer a first order check on the accuracy of OSL_f extraction. It seems unlikely that counting statistics will result in significantly inaccurate OSL_f extraction if the initial OSL signal exceeds about 1000 counts/0.16 s (Fig. 6).

Another factor affecting the accuracy of OSL_f extraction is inaccurate characterization of OSL_m. Although σ_f show great consistence across samples from different environments as reported in literature, σ_m shows more variability (e.g., Shen and Mauz, 2009; Steffen et al., 2009). One approach to verify whether OSL_m of a sample is characterized by the σ_m value adapted here is to conduct an OSL deconvolution analysis. If σ_m value differs significantly from $4.81 \pm 0.27 \times 10^{-18}$

cm^2 does appear, the technique needs to be adapted with a sample specified σ_m value.

Deconvolution analysis applied to the samples used here indicates that all samples tested here have decay constants that are comparable to those derived from published photoionization cross-sections (Table S3).

Counting uncertainty affects the precision of D_e estimates (Galbraith, 2002) and so the reduced variance of smoothed OSL should help increasing D_e precision. The simulation experiment shows that introducing the smoothing process reduces the OSL variance originating from counting statistics (Fig. 1). For D_e calculation, the overall variance reduction achieved through smoothing, results in improved D_e precision (Fig. 5) except for aliquots that with very low signals. This renders the OSL_f extraction technique presented here different from other curve fitting procedures that usually reduce D_e precision. For very low OSL intensities (samples WLD I-1 and WLD I-2, Fig. 5) the precision of $D_{e_OSL_f}$ is worse than the precision of D_{e_bulk} . This is related to the different background subtraction methods: $D_{e_OSL_f}$ utilizes an exponential decay fitted to the last 24 s of stimulation as background whereas the D_{e_bulk} calculation determines background as mean value of the last 8 s of stimulation. Consequently, $D_{e_OSL_f}$ uses a slightly higher background and smaller signal leading to significantly larger uncertainties in case of very dim OSL.

$D_{e_OSL_f}$ may differ from D_{e_bulk} if traps related to OSL_f and OSL_m have different thermal stability or heterogeneous bleaching prior to burial. None of the samples used shows $D_{e_OSL_f} > D_{e_bulk}$ (Fig. 4) which could result from thermally unstable OSL_m . $D_{e_OSL_f}$ equaling D_{e_bulk} for samples CP I-1, GC I-1 and AR I-1 is in agreement with the observed sufficient bleaching of these samples and demonstrates the accuracy of optical dating using OSL_f . In contrast, heterogeneous bleaching should result in $D_{e_OSL_f} < D_{e_bulk}$ if OSL_f is more

sufficiently bleached than OSL_m (Bailey et al., 2003). Samples WLD I-1, WLD I-2 and PV I-4 systematically yield lower $D_{e_OSL_f}$ than D_{e_bulk} , concordant with the presumption that these samples are affected by insufficient bleaching. For all of these three samples accurate OSL ages are achieved using OSL_f , confirming that OSL_f can improve quartz OSL dating accuracy for insufficiently bleached deposits.

The largest D_e s of WLD I-2 occur for aliquots that probably contain very poorly or un-bleached quartz grains. For many of these aliquots $D_{e_OSL_f}$ is not dramatically smaller than D_{e_bulk} (Fig. 4), indicating that OSL_f of these grains is not sufficiently bleached. Therefore, the usefulness of OSL_f dating is limited when bleaching did not produce significantly different residual signals between OSL_f and OSL_m , an issue similar to other approaches for utilizing the most light sensitive OSL components (e.g., Singhvi and Lang, 1998). Major difference between $D_{e_OSL_f}$ and $D_{e_OSL_m}$ are observed on aliquots with relatively low D_{e_bulk} values for both samples, WLD I-1 and WLD I-2 (Fig. S3). Here, bleaching was sufficient to create significantly different residual signals between OSL_f and OSL_m .

7. Conclusions

A simple mathematic method can be used to extract the fast component of quartz OSL using pre-defined parameters. The technique does not rely on curve-fitting deconvolution and can easily be implemented in routine OSL dating due to its mathematical simplicity. Compared to experimental approaches the proposed fast component extraction technique can even be used on quartz with relatively dim OSL only. In addition, smoothing OSL decay curves and optimizing data point selection for fast component calculation can improve the precision of D_e estimates over traditional bulk OSL D_e . Testing on empirical data indicates that optical dating using the

fast component extraction improves the dating accuracy for insufficiently bleached deposits. It also demonstrates that extraction performance depends on the degree to which the fast component was bleached prior to burial.

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Figure and Table captions

Figure 1. Ratio of the variance of smoothed OSL to unsmoothed OSL. Variance is calculated based on 1000 simulated OSL curves (smoothed and unsmoothed) for each scenario ('very dim', 'dim', 'bright'; see Table S2).

Figure 2. Dependence of $RSE(S)$ on t_2 at different t_1 calculated with equation (14) for the 'very dim' OSL scenario.

Figure 3. Examples of empirical OSL of representative samples used in this study. The solid lines are smoothed decay curves. Inserts show typical $D_e(t)$ plots of each sample.

Figure 4. Comparison of D_e calculated using bulk OSL and OSL_f . Each data point represents one aliquot. The solid line in each plot shows the 1:1 correspondence. Data for Wax Lake Delta I-1 and I-2 are plotted in double log scale.

Figure 5. Relative standard error (RSE) of D_{e_bulk} versus $D_{e_OSL_f}$ for all accepted aliquots. The solid line in each plot shows the 1:1 correspondence. Data for Wax Lake Delta I-1 and I-2 are plotted in double log scale.

Figure 6. Recycling ratios plotted against OSL intensity of the first data point of recycling dose OSL. The recycling ratio is calculated using OSL_f . Each data point represents one aliquot. Open symbols represent aliquots with recycling ratios outside a 0.9 to 1.1 range.

Table 1. Samples and analytical results (All uncertainties are quoted at 1σ uncertainty).

References

- Adamiec, G., and Aitken, M.J., 1998, Dose-rate conversion factors: update: *Ancient TL*, v. 16, p. 37-50.
- Arnold, L.J., Bailey, R.M., and Tucker, G.E., 2007, Statistical treatment of fluvial dose distributions from southern Colorado arroyo deposits: *Quaternary Geochronology*, v. 2, p. 162-167, doi: 10.1016/j.quageo.2006.05.003.
- Bailey, R.M., 2010, Direct measurement of the fast component of quartz optically stimulated luminescence and implications for the accuracy of optical dating: *Quaternary Geochronology*, v. 5, p. 559-568, doi: 10.1016/j.quageo.2009.10.003.
- Bailey, R.M., Singarayer, J.S., Ward, S., and Stokes, S., 2003, Identification of partial resetting using De as a function of illumination time: *Radiation Measurements*, v. 37, p. 511-518, doi: 10.1016/S1350-4487(03)00063-5.
- Bailey, R.M., Smith, B.W., and Rhodes, E.J., 1997, Partial bleaching and the decay form characteristics of quartz OSL: *Radiation Measurements*, v. 27, p. 123-136, doi: 10.1016/S1350-4487(96)00157-6.
- Berger, G.W., 1990, Effectiveness of natural zeroing of the thermoluminescence in sediments: *Journal of Geophysical Research: Solid Earth*, v. 95, p. 12375-12397, doi: 10.1029/JB095iB08p12375.
- Choi, J.H., Duller, G.A.T., and Wintle, A.G., 2006, Analysis of quartz LM-OSL curves: *Ancient TL*, v. 24, p. 9-20.
- Cunningham, A.C., and Wallinga, J., 2009, Optically stimulated luminescence dating of young quartz using the fast component: *Radiation Measurements*, v. 44, p. 423-428, doi: 10.1016/j.radmeas.2009.02.014.
- Duller, G.A.T., 2007, Assessing the error on equivalent dose estimates derived from single aliquot regenerative dose measurements: *Ancient TL*, v. 25, p. 15-24.
- Durcan, J.A., and Duller, G.A.T., 2011, The fast ratio: A rapid measure for testing the dominance of the fast component in the initial OSL signal from quartz: *Radiation Measurements*, v. 46, p. 1065-1072, doi: 10.1016/j.radmeas.2011.07.016.
- Galbraith, R.F., 2002, A note on the variance of a background-corrected OSL count: *Ancient TL*, v. 20, p. 49-51.
- Galbraith, R.F., Roberts, R.G., Laslett, G.M., Yoshida, H., and Olley, J.M., 1999, Optical dating of single and multiple grains of quartz from Jinmium rock shelter, northern Australia: Part I. Experimental design and statistical models: *Archaeometry*, v. 41, p. 339-364.
- Gould, H.R., and McFarlan, E.J., 1959, Geologic history of the chenier plain, southwestern Louisiana: *Gulf Coast Association of Geological Societies Transactions*, v. 9, p. 261-270.
- Jain, M., Murray, A.S., and Botter-Jensen, L., 2003, Characterisation of blue-light stimulated luminescence components in different quartz samples: implications for dose measurement: *Radiation Measurements*, v. 37, p. 441-449, doi: 10.1016/S1350-4487(03)00052-0.
- Jain, M., Murray, A.S., Botter-Jensen, L., and Wintle, A.G., 2005, A single-aliquot regenerative-dose method based on IR (1.49 eV) bleaching of the fast OSL component in quartz: *Radiation Measurements*, v. 39, p. 309-318, doi: 10.1016/j.radmeas.2004.05.004.

- Li, B., and Li, S.H., 2006, Comparison of De estimates using the fast component and the medium component of quartz OSL: *Radiation Measurements*, v. 41, p. 125-136, doi: 10.1016/j.radmeas.2005.06.037.
- Murray, A.S., and Wintle, A.G., 2000, Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol: *Radiation Measurements*, v. 32, p. 57-73, doi: 10.1016/S1350-4487(99)00253-X.
- Shen, Z., and Mauz, B., 2009, De determination of quartz samples showing falling De(t) plots: *Radiation Measurements*, v. 44, p. 566-570, doi: 10.1016/j.radmeas.2009.06.003.
- Shen, Z., and Mauz, B., 2012, Optical dating of young deltaic deposits on a decadal time scale: *Quaternary Geochronology*, v. 10, p. 110-116, doi: 10.1016/j.quageo.2012.01.014.
- Shen, Z., Mauz, B., and Lang, A., 2011, Source-trap characterization of thermally transferred OSL in quartz: *Journal of Physics D: Applied Physics*, v. 44, p. 295405, doi: 10.1088/0022-3727/44/29/295405.
- Shen, Z., Törnqvist, T.E., Autin, W.J., Mateo, Z.R.P., Straub, K.M., and Mauz, B., 2012, Rapid and widespread response of the Lower Mississippi River to eustatic forcing during the last glacial-interglacial cycle: *Geological Society of America Bulletin*, v. 124, p. 690-704, doi: 10.1130/b30449.1.
- Singarayer, J.S., and Bailey, R.M., 2003, Further investigations of the quartz optically stimulated luminescence components using linear modulation: *Radiation Measurements*, v. 37, p. 451-458, doi: 10.1016/S1350-4487(03)00062-3.
- Singhvi, A., and Lang, A., 1998, Infrared dating of partially bleached sediments - The differential partial bleach method: *Ancient TL*, v. 16, p. 63-71.
- Smith, B.W., and Rhodes, E.J., 1994, Charge movements in quartz and their relevance to optical dating: *Radiation Measurements*, v. 23, p. 329-333, doi: 10.1016/1350-4487(94)90060-4.
- Steffen, D., Preusser, F., and Schlunegger, F., 2009, OSL quartz age underestimation due to unstable signal components: *Quaternary Geochronology*, v. 4, p. 353-362, doi: 10.1016/j.quageo.2009.05.015.
- Törnqvist, T.E., Kidder, T.R., Autin, W.J., Van der Borg, K., De Jong, A.F.M., Klerks, C.J.W., Snijders, E.M.A., Storms, J.E.A., Van Dam, R.L., and Wiemann, M.C., 1996, A revised chronology for Mississippi River subdeltas: *Science*, v. 273, p. 1693-1696.
- Wintle, A.G., and Murray, A.S., 2006, A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols: *Radiation Measurements*, v. 41, p. 369-391, doi: 10.1016/j.radmeas.2005.11.001.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Table 1

Sample	Expected age (ka) ^a	ø (µm) ^b	d(Gy/ka) ^c	Age model ^d	σ(%) ^e	De (Gy) ^f	Age (ka)
Wax Lake	<0.027	75-180	2.13±0.09	MAMUL	85	0.075±0.007	0.035±0.004
Delta I-1					85	0.042±0.004	0.020±0.002
Wax Lake	0.036-0.069	75-180	2.17±0.10	MAMUL	85	0.197±0.010	0.091±0.006
Delta I-2					107	0.150±0.010	0.069±0.007
Paincourtville	<1.4	100-200	2.47±0.21	MAM	28	2.60±0.30	1.05±0.15
I-4					24	2.50±0.09	1.01±0.10
Chenier	~2.5	125-180	1.39±0.04	CAM	8	3.58±0.07	2.58±0.09
Perdue I-1					7	3.46±0.07	2.49±0.09
Grand	~1.15	125-180	2.01±0.08	CAM	8	2.39±0.05	1.19±0.06
Chenier I-1					7	2.50±0.07	1.24±0.06
Amite River	N/A	180-250	0.21±0.01	CAM	12	6.65±0.15	32±1
I-1					11	6.65±0.14	32±1

a. Age constraints for Wax Lake Delta I-1 and I-2 are from Shen and Mauz (2012), Paincourtville I-4 from Törnqvist et al. (1996), Chenier Perdue I-1 and Grand Chenier I-1 from Gould and McFarlan (1959).

b. Particle size of quartz used for OSL measurement.

c. Natural dose rate.

d. MAMUL: unlogged minimum age model of Arnold et al. (2009), MAM: minimum age model and CAM: central age model of Galbraith et al. (1999).

e. Overdispersion of dose distribution.

f. Values in italic bold are based on the fast component analyses.