**Appendix C1.** **The bandwidth for kernel density estimate (KDE) plot**

The first type of option for bandwidth of KDE in LDAC is to provide a fixed bandwidth, such as ‘Silverman331’ (Silverman, 1998, p. 47-48),

and (C1.1)

where is the standard deviation of observed equivalent dose ()values and IQR is the interquartile range, the difference between upper and lower quartiles. Larger bandwidth yields less graphical peaks, potentially obscuring data subpopulations. In contrast, a smaller may yield insights into multiple populations, but it might display more essentially ‘noise’ (Silverman, 1998, p. 7-50, Galbraith and Roberts, 2012; Vermeesch, 2012). Users can also select the ‘User-defined’ in the list to input a user-specified value.

The second type of option is ‘Adaptive’ bandwidth (Botev et al., 2010; Vermeesch, 2018), which replaces the fixed bandwidth in Eq. (9) of the main text with a local bandwidth . The local parameter is calculated by

, (C1.2)

, (C1.3)

where is the observed value for each aliquot or grain ; is the density at point evaluated by a fixed bandwidth ; is the number of valid data points. If the ‘Adaptive’ is chosen, the will be derived from Eq. (C1.1). If the ‘User-adaptive’ is chosen, the constant is equal to the input value.

The third option is the probability density functions (PDF) when ‘PDF plot’ is chosen, where the bandwidth in Eq. (9) is replaced by the analytical uncertainties . Thus, the PDF for a set of observed values ,

, (C1.4)

The high precision data in PDF will have higher peaks, and low precision data are smoothed out by a broad kernel (Galbraith and Robert, 2012).

**Appendix C2. Statistical principle of common age model and finite mixture model (FMM).**

1. Common age model

The common age model assumes that the true equivalent dose ( may be the same or very similar for all aliquots or grains, and consistent with a common value with no additional dispersion to consider. This common value of a set of observed values for aliquot or grain is usually estimated by a standard weighted average method (Taylor, 1997, p173-179; Galbraith, 2005, p. 47-50; Galbraith and Robert, 2012),

 (C2.1)

 (C2.2)

The standard error of the maximum likelihood estimate could be approximately:

 . (C2.3)

This method also known as ‘inverse variance weighted mean’ (Taylor, 1997, p. 173-179; Galbraith and Roberts, 2012).

This common age model can also be applied to log-transformed data, especially for the data set that are positively skewed. In this case, the and in Eqs. (C2.1-C2.3) are the natural log of observed value and its relative standard error, respectively.

1. Finite Mixture model (FMM)

The FMM assumes that a sample contains several discrete components, where individual components represent different depositional events (Galbraith and Robert, 2012). The FMM can be employed to identify these individual components from mixture sediments. The statistical principle of the FMM can be referred to Galbraith (2005, chapter 5). This discrete mixture is described by:

 (C2.4)

 (C2.5)

 (C2.6)

 (C2.7)

where is the number of components, is the proportion of the aliquots or grains that belong to the th component, thus the sum of is 1; is the mean of the th component; and are the natural log of and relative standard error (observed values and absolute errors in normal scale); the is an additional dispersion, as with in minimum age model (MAM); is the contribution of to the th components. The unknown parameters and can be estimated when the log-likelihood reaches a maximum (Galbraith,2005, p. 90-105), where

. (C2.8)

The number of k in LDAC for given data sets is evaluated by the Bayes Information Criterion (BIC) method (Galbraith and Roberts, 2012):

 (C2.9)

where is the number of fitted parameters, is the number of observed values, and the is the maximum likelihood. The most appropriate component number in Eq. (C2.4) corresponds to the smallest BIC (Galbraith and Roberts, 2012).

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