

# CoRSEER: The Calculator of Rock Surface Exposure Age and Erosion Rates for Rock Surface Luminescence dating

Author(s): Arbaz N. Pathan et al.

MS No.: egusphere-2026-1303

Referee Comments are in black.

The author's comments are in blue.

CoRSEER is exactly what the luminescence community needs right now. It provides much-needed standardisation of the method, but also increases the accessibility of this technique. This is a major step-forward in the technique. The CoRSEER calculator is accompanied by this well explained paper, which shows how much testing has gone into it, which gives confidence to the user. It also acts as somewhat of a reference 'manual' for those less expert in the technique, which is a very useful addition to the literature. With this in mind, I have a few comments below where this paper could provide a little more instruction/guidance on the technique more generally (beyond just CoRSEER) given that it will be such a key reference paper for the technique. The paper identifies and tackles the issues with defining the saturated plateau at depth, providing a solution shown to reduce uncertainties quite dramatically, and presumably improve the accuracy – an important advancement as anyone who has tried to model luminescence depth profiles will know. This is an excellent addition to the literature and luminescence toolkit, and the authors should be commended for all their hard work on developing it. I include a few very minor comments below for the authors to consider.

We acknowledge your efforts in going through the minute details of this work and your very positive, encouraging, and constructive feedback. We appreciate your recognition of CoRSEER as a step forward for standardisation in the luminescence community. Below are our point-by-point responses to your specific comments. We have incorporated all the suggestions in the manuscript and modified the source code accordingly.

## Specific Comments:

I may have missed it in the paper, but it would be good to know how the uncertainties are derived for the erosion rates. A short description in Section 3.2 could help.

We acknowledge the referee for this suggestion. Now, we have added the codes to derive uncertainty in erosion rates, which were previously missing.

We have added a plot in CoRSEER III: Erosion Estimation, where the error estimation can be visualised.

Further, we have added a short description in Section 3.2.3 L279 as:

"Furthermore, we perform a Gaussian distribution operation on  $\dot{\epsilon}$  column associated with steady erosion onset exposure age ( $t_{ss}$ )"

The detailed description of error estimation is provided in the Supplementary Section 4.3.2 L321-330

"The main objective was to extract the minimum erosion-onset time at which the best-fit erosion solution becomes stable, and then estimate the representative erosion rate with uncertainty using a Gaussian probability distribution. The analysis was performed using the final misfit/probability matrix generated during the erosion-age modelling step. At first, we search for the best-fitting values in each column associated with each  $t_s$ . The unique best-fitting pairs of  $\dot{\epsilon}$  and  $t_s$  is smoothed using the moving median interpolation method. The algorithm searches for the point where the slope of this line becomes zero, and then the closest matrix associated with that point is chosen for the Gaussian distribution operation to calculate the mean and  $\pm 1\sigma$ . It must be noted that the in-built parameter to detect the onset time of erosion is adjusted based on the analysed dataset and might fail in some exceptional circumstances. In that case, we suggest using a matrix of the erosion rates, the onset time of erosion and the resulting *norm\_chi* can be used to perform the Gaussian probability distribution operation manually. We recommend the user to adjust the limits of erosion and/or increase resolution to enhance the quality of the dataset."

Added the modified results in Section 4.3 L376-L380:

"The CoRSEER-III-derived erosion rates broadly agree with the literature erosion-rate values. The literature erosion rates range from 0.0035 to 4.3 mm/a, whereas the CoRSEER-III-derived erosion rates range from 0.003 to 4.327 mm/a. Using the literature values as reference, the absolute percentage difference ranges from 0.6% to 86.7%. The minimum difference occurs for IR50\_MBTP6, where CoRSEER-III gives 4.327 mm/a compared with the literature value of 4.3 mm/a. The largest difference occurs for IR50\_MBTP5, where CoRSEER-III gives 0.560 mm/a compared with the literature value of 0.300 mm/a.

The uncertainty associated with CoRSEER-III-derived erosion rates remains within a reasonable range for most samples. The relative upper error in the CoRSEER-III erosion rates varies from 10.8% to 44.9%, whereas the relative lower error varies from 10.8% to 33.3%. The lowest relative uncertainty occurs for IR50\_MBAM2, where the erosion rate is 0.037 mm/a with an uncertainty of approximately  $\pm 10.8\%$ . The highest upper uncertainty occurs for IR50\_BALL02, where the upper error reaches

approximately 44.9%. These values show that the algorithm provides bounded erosion-rate estimates rather than single manually selected solutions.

In contrast, the erosion-onset time,  $t_{ss}$ , shows a considerably larger departure from the literature values. The literature  $t_{ss}$  values range from 4 to 3146 a, whereas the CoRSEER-III-derived  $t_{ss}$  values range from 3 to 3080 a. Using the literature values as reference, the absolute percentage difference ranges from 18.0% to 64.1%. In most samples, CoRSEER-III estimates a younger erosion-onset time than the literature value. The only exception is IR50\_MBTP1, where CoRSEER-III gives a larger onset time of 3080 a compared with the literature value of 2610 a, corresponding to an increase of approximately 18.0%. The maximum difference occurs for IR50\_MBTP5, where CoRSEER-III estimates 23 a compared with the literature value of 64 a, corresponding to a reduction of approximately 64.1%.

Overall, the results indicate that CoRSEER-III reproduces the erosion-rate field reasonably well, as presented in Table 5, but it estimates erosion-onset time differently from the literature. This difference is expected because the CoRSEER-III estimate is derived from an automated best-fitting erosion-time slope detection algorithm, whereas previous studies relied more strongly on manual or interpretative selection of model solutions."

We modified the discussion accordingly in Section 5.4 L480-489:

"One of the most important observations is that CoRSEER-III captures the same broad erosion-rate scale as the literature values. This indicates that the erosion-rate extraction algorithm is able to preserve the first-order structure of the erosion solution space. In practical terms, this is encouraging because the algorithm avoids subjective manual picking while still recovering erosion-rate estimates comparable to previous studies. This is also a possible reason for the large relative difference between CoRSEER and literature results in a few cases. Thus, for maximum accuracy and precision, we recommend following the guidelines. The users should not run the model once over a very large erosion-exposure window and treat the result as final. A better strategy is to run the model in multiple stages. First, use a broad search window to identify the approximate high-likelihood region. Then shrink the exposure-erosion window around that region. Finally, increase the matrix density so that the best-fitting slope is resolved with higher numerical precision. This stepwise refinement should reduce grid artefacts and improve the stability of both erosion-rate (and errors) and onset-time estimates."

In Section 3.2, please could you also explain to the reader why you provide the median alongside the best fit. What use could it have, in addition to the best fit?

The best-fit value represents the highest-probability or least-misfit solution, whereas the median represents the central value of the accepted parameter after the Bayesian approach. Ideally, both values should be the same. If the matrix resolution is low or the input range is too broad or the input parameter range is biased toward higher or lower values, the median may deviate substantially from the best-fit value. Therefore,

we report both values, use the best-fit value for subsequent calculations, and ensure that the best-fit and median values remain close in the final analysis.

We have added a sentence in Supplementary Section 4.1.2 L193-197 as:

"It must be noted that both the best fitted value and median of accepted values after the Bayesian approach should, ideally, overlap with each other. However, if the matrix resolution is low or the input range is too broad or the input parameter range is biased toward higher or lower values, the median may deviate substantially from the best-fit value. Thus, for precise and accurate output, the input calibration parameter range and the number of pairs must be adjusted in such a way that the best-fit and median should be closest to each other"

The landform dated in Smedley et al. (2021) was a rock avalanche, not just an avalanche. It's worth saying this explicitly.

We have updated all references from "avalanche" to "rock avalanche" throughout the manuscript.

Line 296 – Given the importance of using the GOK for fitting luminescence depth profiles determined for feldspar, it would be useful to add a few words to the end of the sentence to emphasise this to the reader. For example, "However, CoRSEER has the flexibility of using  $r > 1$ , which is important when fitting data derived from feldspar that is not described by first order kinetics". Or something similar that you would advise.

Thank you for the suggestion. We have added the sentence shown in the line L309-311.

"However, CoRSEER has the flexibility to use  $r > 1$ , which is important when luminescence depth profiles are derived using feldspar IRSL, which follows non-FOK behaviour."

Section 5.2 – this section provides some recommendations on the age of the sample used for calibration (i.e. younger is better as they will have been subjected to less erosion). However, it does not mention anything about the factors that can influence the attenuation rate ( $\mu$ ) or  $\sigma_{\text{phi}}$ . Given that this paper is likely to be a key reference for the community in this technique, it is worth using a short paragraph to emphasise the importance of rock opacity, surficial coatings, aspect and other factors on  $\mu$  and  $\sigma_{\text{phi}}$  (e.g. Luo et al. 2018; Meyer et al. 2018; Ou et al. 2018; Smedley et al. 2021, 2025; Fuhrmann et al. 2022; Cui et al. 2024). It would be good to make sure that the reader understands the importance of ensuring that the characteristics controlling  $\mu$  and  $\sigma_{\text{phi}}$  of the calibration sample are identical to the unknown sample.

Literature review in the context on what factors affect the sigma phi and mu in context of rock opacity, surficial coating, aspect (Solar insolation) and many more. That means

We appreciate your suggestion and understand the necessity to add a section discussing these micro and macro factors influencing the calibration.

We have added a new paragraph in Section 5.2 L445-456 as:

"When selecting a calibration sample, it is critical to recognise that the light attenuation coefficient ( $\mu$ ) and the effective detrapping rate at the surface ( $\overline{\sigma\varphi_0}$ ) of the calibration samples are the best representatives of the actual sample. Recent empirical studies demonstrate that photon penetration and attenuation are highly sensitive to micro-mineralogical heterogeneity, such as the spatial distribution of opaque and translucent minerals, which can cause localised 'light piping' or 'shadowing' (Meyer et al., 2018; Cui et al., 2024). Furthermore,  $\mu$  is strongly wavelength-dependent and can be drastically altered over time by dynamic surficial boundary conditions, including the accretion of rock varnish (Luo et al., 2018) or localised iron-hydroxide precipitation due to moisture (Meyer et al., 2018; Smedley et al., 2021). The effective detrapping rate ( $\overline{\sigma\varphi_0}$ ) is similarly sensitive to external environmental geometries, fluctuating significantly based on the target surface's topographic aspect, inclination, and seasonal solar incidence angles (Fuhrmann et al., 2022). High-resolution spatial analyses reveal that these optical properties can vary significantly even on a sub-millimetre scale within contiguous rock formations (Ou et al., 2018; Smedley et al., 2025). Consequently, to avoid severe systematic chronological errors, it is imperative to ensure that the optical characteristics, dynamic surficial coatings, and spatial orientation governing  $\mu$  and  $\overline{\sigma\varphi_0}$  in the calibration sample, the measurements are meticulously matched to those of the unknown target sample."

Section 5.4 is quite short. Could you further comment on whether CoRSEER improves accuracy and precision of erosion rates? Expand more on deriving transient erosion rates.

We have appended discussion section 5.4 L480-489, which is already mentioned in earlier comments, emphasising accuracy and precision in presenting the limitations associated while deriving transient erosion rates.

Line 356 – space missing.

Done

Consistency of "CoRSEER" vs "CoRSEEr". (Standardised to CoRSEER).

Done